ELIMIA CURVICOSTATA SPECIES-COMPLEX WITHIN THE RIVER DRAINAGES OF THE SOUTHEASTERN UNITED STATES: MORPHOLOGY, DNA AND BIOGEOGRAPHY

BY

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by

Elizabeth Louise Mihalcik

This is dedicated to my dogs Annie, Buffy, Darwin, Benjamin, Nickie, and Gina who accompanied me on this journey

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Elizabeth Louise Mihalcik

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Chairman: Dr. F. Wayne King
Major Department: Wildlife Ecology and Conservation

Elimia (=*Goniobasis*) *curvicostata* was composed of 1-9 synonymized species based on prior studies. The complex's distribution encompasses the Gulf and Atlantic coastal rivers of Florida, Georgia, and Alabama. One hundred and nine localities were surveyed. Shell morphology was used to differentiate between *E. curvicostata* and the other species within the region. These results indicated that *E. densicostata* not *E. curvicostata* inhabited these rivers. Mitochondrial DNA was also used to genetically discriminate between the species. The region's phylogeny revealed an eastern and western assemblage which is similar to the genetic findings of other taxa studied in the region.

Canonical Discriminant Analyses detected a significant p-value <0.01 in morphological differences between the species. The first three canonical variables explained 96.5% of the variation. The adult shell length, aperture length, aperture

height aperture width ApW/ApH and the rib number on the penultimate whorl were important factors characterizing the first three canonical variables

Examination of the types revealed that wild populations in the Apalachicola River system resembled *Melania densicostata* Reeve 1861 and not *Melania curvicostata* Because of the distinctive sculpture the types identified as *Melania curvicostata* resemble populations of the species group *E edgariana* found in the Tennessee River system Also *Goniobasis dooleyensis* and *G induta* are synonymous with *Elimia (=Melania) densicostata*

The mitochondrial DNA analyses used a 324 bp sequence of cytochrome oxidase gene subunit I to differentiate between the taxa *Elimia dickinsoni* *E taitiana* *E bentoniensis* and the outgroup *Pachychilus obeliscus* were also used in the analyses Maximum parsimony and the Kimura two parameter model gave identical trees *Elimia densicostata* *E. viennaensis* and the Choctawhatchee and Escambia *Elimia* were genetically distinct with nucleotide divergence between 9-20%

Phylogenetic analyses revealed an eastern and western assemblage The eastern assemblage includes *Elimia densicostata* and *E dickinsoni* These two species are closely related to the Atlantic Coastal *E timida* with a confidence level of 85% The western assemblage includes the Choctawhatchee and Escambia River *Elimia* These two *Elimia* species are related to *E olivula* of the lower Alabama River with a confidence level of 100%

CHAPTER 1
INTRODUCTION

Taxonomic Overview

The freshwater prosobranch snail, *Elimia curvicostata*, is a member of the family Pleuroceridae. The pleurocerid family contains approximately 8 genera endemic to North America (Thompson 1984). The pleurocerid genus *Elimia* (=*Goniobasis*) is distributed throughout North America and is found exclusively east of the continental divide (Burch and Tottenham 1980, Burch 1982, 1989, Thompson 1984). This genus contains approximately 500 nominal species which are based exclusively on qualitative adult shell characters such as shape, sculpture, color and banding (Figure 1A) (Thompson 1984). However, the current classification recognizes only 106 species within the North American fauna (Figure 1B) (Burch 1989). The other 394 nominal names are synonymized under the names recognizes in the current fauna.

Prior studies concerning the southeastern fauna have addressed quantitative shell characters such as the dimensions of the spire, body whorl, and aperture for only a few individuals within a species (Tryon 1863-1895, 1873, Goodrich 1934a-c, 1935a-b, 1942; Clench and Turner 1956; Chambers 1990). This limited amount of information on intraspecies and interspecies shell morphological characters has led to many conflicting views within the literature on what constitutes a species within this group

The abundance of convergent shell characters in *Elimia* has resulted in taxonomic confusion (Thompson 1982, 1984). This confusion has led to a superficial classification for the many *Elimia* species that inhabit the southeastern river drainages. Because of the phenomenal number of *Elimia* species that inhabit North America, this study is restricted to the species-complex of *Elimia curvicostata* and other smooth morphological forms within the southeastern river drainage systems of Florida, Georgia and Alabama. This investigation will only address a small fraction of the *Elimia* fauna and of the species names occupying the literature (Table 1, Figure 1C).

Historical Background

Eight individuals have played major roles in the characterization of the southeastern *Elimia* fauna--Isaac Lea, Lovell Reeve, George W. Tryon, Calvin Goodrich, William Clench, William Okkelberg, Ruth Turner, and Steve Chambers. Lea (1834, 1840, 1842, 1845, 1848, 1861, 1862a, 1862b, 1862c, 1862d, 1863, 1867, 1868a, 1868b, 1869, 1869b, 1874), the first naturalist to study the many species of *Elimia* within the North American rivers, was responsible for the majority of the described pleurocerid species.

The second important individual was Reeve from the British Museum (Dance 1966). Reeve acquired the *Elimia* from the collection donated by Cumming, an Englishman, to the British Museum. Reeve (1859-1861) described many of the New World pleurocerid species within the first monograph of this family, *Conchologia Iconica*. This was the first publication to depict the North American molluscan fauna with color plates and black and white line drawings. Within this major work, many of Lea's previously published descriptions were illustrated. The earliest major synthesis of the North American pleurocerid fauna was attributed to Tryon (1864, 1873). He

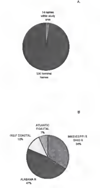

FIGURE 1 North American *Elimia* species A. Fourteen of the nominal names within the literature are reviewed out of the 500 nominal names within the literature B The number of North American *Elimia* species according to Burch (1989) C The total number of recognized species that occur in the Gulf Coastal rivers according to Burch (1989)

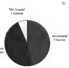

FIGURE 1--continued

TABLE 1 **Original taxonomic designations of southeastern *Elimia*. Species names and their type localities that are relevant to this study**

Species	Type Locality
Melania modesta Lea 1845	Chattahoochee River Columbus, Georgia
Melania curvicostata Reeve 1861	Florida United States.
Melania densicostata Reeve 1861	Florida. United States
Goniobasis doolyensis Lea 1862	Near Vienna in a small stream tributary to Flint River Dooly County Georgia
Goniobasis elliotti Lea 1862	Little Uchee River Alabama
Goniobasis etowahensis Lea 1862	Etowah River Georgia
Goniobasis inclinans Lea 1862	Near Albany Georgia
Goniobasis induta Lea 1862	Near Vienna Dooly County Georgia
Goniobasis inosculata Lea 1862	Little Uchee River below Columbus Georgia
Goniobasis mutabilis Lea 1862	Butts County Georgia.
Goniobasis ucheensis Lea 1862	Little Uchee River Alabama
Goniobasis viennaensis Lea 1862	Tributary of the Flint River Georgia near Vienna
Goniobasis gesneri Lea 1868	Uchee River Alabama
Goniobasis mutabilis timidus Goodrich 1942	Spring 2 miles NW of Hawkinsville Pulaski County Georgia.

consolidated all of the described species of pleurocerids in North America under a Tryon was also responsible for the species synonymies of the pleurocerids within the scientific literature at that time (Table 2)

The first attempt to classify the pleurocerids into related groups was by Goodrich (1934a-c, 1935a-b, 1937, 1938, 1942). However, he chose to group species on the basis of shell sculpture and disregarded all other morphological characters (Table 3). He also described several new *Elimia* (=*Goniobasis*) species within these southeastern drainages (Goodrich 1921, 1924, 1935a-b, 1939, 1942). However Goodrich relied on prior collections by Clench and Okkelberg for many of the pleurocerids that Goodrich discussed within his publications.

The primary survey of the southeastern molluscan fauna was by Clench, Okkelberg, and Turner in the mid-1900s. After several expeditions to the southeastern rivers, Clench and Turner (1956) published the survey results from the Suwannee River system westward to the Escambia River system. Furthermore, the document described detailed locality information for the entire distribution of mollusk species within the region (Table 4).

Burch (1982, 1989) published the first notable volume documenting the freshwater snails of North America. It was this manual that first employed the genus name *Elimia* rather than *Goniobasis*. This volume represented the currently recognized taxonomic species of pleurocerids and their distributions within the North American river drainages (Table 5).

TABLE 2. *Elimia* species of the southeastern US recognized by Tryon Jr (1864, 1873). Synonymous species (if any) are listed for each recognized species.

SPECIES RECOGNIZED	SYNONYMOUS SPECIES	REGIONAL DISTRIBUTION
Goniobasis curvicostata (Reeve 1861)	*Melania curvicostata* Reeve 1861 *Melania densicostata* Reeve 1861	Florida, United States.
Goniobasis doolyensis Lea 1862	*Goniobasis doolyensis* Lea 1862 *Goniobasis induta* Lea 1862	Near Vienna, Dooly County, Georgia
Goniobasis etowahensis (Lea 1862)	*Melania etowahensis* Lea ms. Reeve 1861 *Goniobasis canbyi* Lea 1862	Etowah and Tennessee Rivers.
Goniobasis inclinans Lea 1862	None	New Albany, Georgia; Etowah Tuscumbia, Alabama
Goniobasis tripartita Reeve 1860	*Melania tripartita* Reeve 1860	Locality Unknown.
Goniobasis symmetrica (Haldeman 1841)	*Goniobasis ucheensis* Lea 1862	Georgia, Alabama, Tennessee
Goniobasis viennaensis (Lea 1862)	None	Near Vienna, Dooly County, Georgia

TABLE 3 *Elimia* species of the southeastern US recognized by Goodrich (1935, 1939, 1942). Synonymous species (if any) are given for each recognized species

SPECIES RECOGNIZED	SYNONYMOUS SPECIES	REGIONAL DISTRIBUTION
Goniobasis curvicostata (Reeve 1861)	? *Melania tripartita* Reeve 1860 ? *Melania densicostata* Reeve 1861 *Goniobasis doolyensis* Lea 1862	Streams of western Georgia and Florida rivers and creeks of southeastern Alabama
Goniobasis uchеensis Lea 1862	*Goniobasis gesneri* Lea 1868	Uchee and Little Uchee creeks Russell County, Alabama
Goniobasis boykiniana viennaensis (Lea 1862)	? *Melania suturalis* Haldeman 1840 ? *Trypanostoma fartum* Lea 1862 *Goniobasis elliottii* Lea 1862 (in part)	Flint River, creeks of western Georgia, the upper Ogeechee River, Georgia, Uchee Creek, Alabama
Goniobasis induta Lea 1862	None	Flint River basin, Crisp and Dooly Counties, Georgia

TABLE 4 *Elimia* species of the southeastern US recognized by Clench and Turner (1956). Synonymized species (if any) are listed for each recognized species

SPECIES RECOGNIZED	SYNONYMOUS SPECIES	REGIONAL DISTRIBUTION
Goniobasis curvicostata (Reeve 1861)	*Melania curvicostata* Reeve 1861 *Melania densicostata* Reeve 1861 *Goniobasis doolyensis* Lea 1862 *Goniobasis inclinans* Lea 1862 *Melania induta* Lea 1862 *Goniobasis ucheensis* Lea 1862 *Goniobasis elliottii* Lea 1862 *Goniobasis gesneri* Lea 1866	Flint River of the Apalachicola River drainage system westward to the Escambia River drainage system
Goniobasis viennaensis (Lea 1862)	None	Restricted to the tributaries of the Flint River within the Apalachicola River drainage system

TABLE 5 *Elimia* species of the southeastern US recognized by Burch (1982 1989) Synonymized species (if any) are listed for each recognized species

SPECIES GROUPS RECOGNIZED	SPECIES ASSOCIATED	REGIONAL DISTRIBUTION
Elimia boykinniana group	*Elimia boykinniana viennaensis* (Lea 1862)	Flint River and creeks of western Georgia Uchee Creek Russell County Alabama (Goodrich 1942)
	Elimia ucheensis (Lea 1842)	Uchee and Little Uchee creeks Russell County Alabama (Goodrich 1942)
Elimia carinocostata group	*Elimia curvicostata* (Reeve 1861)	Streams of western Georgia and Florida Rivers and Creeks of southeastern Alabama (Goodrich 1942)
	Elimia induta (Lea 1862)	Flint River Basin Crisp and Dooly counties Georgia (Goodrich 1942)
Elimia catenaria group	*Elimia inclinans* (Lea 1862)	Flint River tributaries, Georgia (Goodrich 1942)
Elimia mutabilis group	*Elimia mutabilis mutabilis* (Lea 1842)	Streams of western Georgia and Florida and and southern Alabama few creeks and springs of Alabama within the Alabama River system (Goodrich 1942)
	Elimia mutabilis timidus (Goodrich 1942)	Spring two miles northwest of Hawkinsville Pulaski County Georgia in the basin of the Altamaha River (Goodrich 1942)
	Elimia taitiana (Lea 1841)	Branch of Sepulga River, Conecuh County Alabama small streams of the Alabama River system Sumpter Marengo Monroe and Wilcox counties Alabama (Goodrich 1942)

Chambers (1990) provided the most recent revision of the southeastern *Elimia* fauna (Table 6) and designated lecto- and paralectotypes for all the southeastern species. Within this revision, Chambers synonymized many of the *Elimia* species described early in the 19th Century. Unfortunately, he did limited field work and relied heavily on museum specimens. He also arrived at his conclusions by qualitative shell characters and disregarded quantitative shell characters.

The Problems Associated with Taxonomic Studies

Many problems associated with taxonomic studies may be relevant to *Elimia* classification including prior collected material, omitted information, and human error. In the past, taxonomic descriptions of species and genera were delegated almost exclusively to museum-based researchers. The taxonomists were rarely the original collectors and often acquired their specimens second-hand. The collector of the specimens was considered unimportant information and often omitted from the description. It was not uncommon that the date of collection and the specific locality information were never recorded and kept with the specimens. Many private shell collections were assembled by trading with other collectors and some of these private collections were subsequently donated to museums. Museums accepted such collections because often they were the only source of scientific information. This investigation reflects all of the problems associated with taxonomic studies. The original source of *Elimia* shells came from John G. Anthony, an American shell collector and naturalist. It can be assumed that Anthony might have received these specimens while trading because he did not personally visit Florida in his travels (Anthony, unpublished letters). The *Elimia* shells eventually ended up in the Cumming Collection that was later donated to the British Museum.

TABLE 6 *Elimia* species of the southeastern US recognized by Chambers (1980). Synonymous species (if any) are listed for each recognized species.

SPECIES RECOGNIZED	SYNONYMOUS SPECIES	REGIONAL DISTRIBUTION
Elimia curvicostata (Reeve 1861)	*Melania curvicostata* Reeve 1861 *Melania densicostata* Reeve 1861 *Goniobasis etowahensis* Lea 1862 *Goniobasis doolyensis* Lea 1862 *Goniobasis viennaensis* Lea 1862 *Goniobasis induta* Lea 1862 *Goniobasis ucheensis* Lea 1862 *Goniobasis inosculata* Lea 1862 *Goniobasis elliottii* Lea 1862 *Goniobasis gesneri* Lea 1862 *Goniobasis canbyi* Lea 1868	Apalachicola River drainage system west to the Escambia River drainage system
Elimia boykiniana (Lea 1840)	*Goniobasis gesneri* Lea 1868	Econfina River east to the Suwannee River drainage system.
Elimia floridensis (Reeve 1860)	*Goniobasis inclinans* Lea 1862 *Goniobasis etowahensis* Lea 1862	Choctawhatchee River drainage east to the St. John's River drainage.

The Taxonomic Focus of this Study

Elimia curvicostata was originally described as *Melania curvicostata* Reeve 1861 from an unknown type locality in Florida. Recently *E. curvicostata* was redefined as a species-complex, composed of many species that have been previously recognized as distinct taxa (Thompson 1984). Prior studies had a tendency to synonymize similar looking morphological forms under this single name while giving no categorical or detailed rationale for these conclusions (Tryon 1864, 1873, Goodrich 1942, Clench and Turner 1956, Chambers 1990). Because these synonymies were based exclusively on superficial shell characters, potentially valid taxonomic species may have been subsumed. These prior studies were based solely on specimens collected second-hand with little regard for the biogeography of the southeastern freshwater fauna.

The investigation reported here used shell morphometrics and mitochondrial DNA to analyze the various forms placed under this species-complex. Twelve quantitative shell characters were used to differentiate among the potential species-taxa. Multivariate statistical analysis of the morphological data demonstrated significant differences between the forms, with potential applications in identifications. Nonetheless, the species relationships could not be completely resolved by these same criteria. Shell morphology provided evidence for parallel evolution or convergence among distantly related taxa within the southeastern *Elimia* fauna.

This study used part of the cytochrome c oxidase gene segment (CO1) of the mitochondrial DNA to differentiate between taxa. Other studies revealed that cytochrome oxidase was able to distinguish among closely related vertebrate and invertebrate species and sibling species that were otherwise difficult to distinguish morphologically (Jacobs et al. 1988, Uehara and Shingaki 1985). By using the CO1 gene, intra- and interspecies differences among the *Elimia* were assesed within the region. This assessment provided the genetic basis for each of the species identities and their relationships within the river drainages.

Study Objectives and Implications

In this study I will address three major concerns in the southeastern freshwater fauna—biodiversity, biogeography, and conservation. The southeastern US molluscan fauna is the third largest assemblage of *Elimia* in North America (Figure 1B). The most recent assessment of *Elimia* species had concluded that their number had been greatly inflated (Chambers 1984, 1990). Furthermore, many of the originally described species that were phenotypically different were proposed to be a single species. It is this complication within the literature that has led to a discrepancy in differentiating among species within the region. Can species identifications be adequately assessed with classical shell morphology? This investigation was able to confirm that shell characters were necessary and essential for discriminating among species. Also, species groupings were consistent with genetic separations. Can the morphological and genetic characters adequately determine the relationships among the taxa? This study was able to show that the relationships among the taxa were grouped differently depending on the data set used in the analyses. Shell characters was used to demonstrate convergence among the taxa, not genetic relatedness within the region.

The biogeography of the region will be re-examined for each of the river drainage systems. After Chamber's study (1990), southeastern biogeography was altered by implementing a much wider distribution for a single species. This single species taxon now inhabited several drainages rather than being confined to a single river drainage (Thompson 1984). This finding altered the distribution formerly reported for the many species within the region. So, this study re-examined the number and distribution of the endemic species within the study area.

Phylogeography, a component of biogeography also was addressed within the southeastern rivers. Phylogeography is the relationship between phylogeny and geography (Avise et al. 1987). Can the phylogeny of the species-taxa reflect the distribution of these taxa? Can the current taxa reflect the historical movement of fauna between the river drainages? How does the biogeography and phylogeography of *Elimia* relate to other freshwater organisms within the same region?

CHAPTER 2
MATERIALS AND METHODS

Field Collection Methodologies

Animal Description

The southeastern *Elimia* are typically recognized by their shell shape, size, and sculpture. They have elongated conical-shaped shells which are extremely thick and solid in appearance (Figure 2A-2B). The adults range in length from 10 mm to 25 mm.

The species within the region may have one to several characteristic sculpture patterns--vertical ribs, spiral cords or nodules (Figure 2A). The appearance of nodules results when the spiral cords intersect the vertical ribs. The ribs also may vary in their relative shape and thickness. However, the position, quantity, and general appearance of these sculpture patterns may vary according to age and geographical variation.

The shell color of the southeastern *Elimia* is limited and consistent with the other species outside their range. The color is found only on the thin outer surface, the periostracum, and varies from shades of brown to olive-green. Some *Elimia* populations have colored spiral bands encircling the whorls. These bands range from reddish to dark brown. In some populations, the shell color may appear black. However, this black color is due to staining produced by high concentrations of tannins in the water.

Like all pleurocerid snails in the order Prosobranchia, *Elimia* also have an operculum. This structure is characteristic in pleurocerid snails placing them under the order prosobranchia. The operculum is a thin, corneous plate on the bottom of the foot muscle that serves as a trap door, sealing the aperture when the snail withdraws back into its shell. The operculum is usually brownish in color. However, it may also be stained black.

The color of the head and foot regions varies among the species. However, this aspect of their biology has not been well-documented within the literature. The soft parts are usually less noticeable because the snail typically withdraws back into its aperture when disturbed. The soft, exposed parts consist of a pale grayish-blue background with alternating luminescent blue or orange stripes. The tentacles are black, alternating with white and yellow rings towards their ends. However, the intensity, quantity, and combination of these colors may vary according to species.

The Study Area

The study area consisted of several major and minor river drainage systems of the Gulf coastal and southern Atlantic coastal plains (Figure 2C). This area was determined using the distributions of the *Elimia* species recorded by prior investigations within the region (Goodrich 1934a-c, 1939, 1942; Clench and Turner 1956). The river drainages from the Escambia River system eastward to the Apalachicola River system were sampled for smooth forms of *Elimia* (Figures 3-6; Tables 8-10). The smaller tributaries of the lower end of the Alabama River which lie adjacent to the Escambia River were surveyed for similar morphological forms (Figure 2; Table 7). The rivers within the southern Atlantic coastal plain which include Briar Creek and the Altamaha, Ogeechee, and Savannah Rivers were surveyed for comparative material (Figure 7; Table 11).

Field Collection

Live snails were collected mechanically by hand and with a small hand-held, metal kitchen strainer Large snails were found attached to vegetative debris rocks and bridge pilings The small-screened metal strainer was used in collecting small juvenile snails and adults burrowing through the soft substrate that would have otherwise been overlooked Between 50 and 100 adult sized snails (10-25 mm in length) were collected from each locality At each locality the stream was surveyed for approximately 100 meters on both sides Snails were collected at below normal water levels where they are easily spotted crawling in the shallow areas Snails could not be collected during normal to high water conditions because the animals were under more than 1 5 meters of fast moving water

The snails were placed inside a plastic or glass container and covered with creek water The bottles were kept on ice and transported back to the laboratory Snails were stored at refrigerated temperatures in the laboratory This step is extremely crucial for keeping the snails viable until they could be sorted out for the various analyses Cooler temperatures kept the animals in a dormant state which reduced the amount of waste produced in the bottle The animals would expire if the water was not changed on a daily basis

Specimens from each locality were set aside for morphologic and genetic studies The majority of snails were dried as shell specimens and deposited in the Florida Museum of Natural History Division of Malacology

Data Collection

The localities within this region were sampled between 1993 and 1997 The sample locations are indicated in their respective tables (Tables 7-11) Also, localities that were not visited personally but examined from only voucher specimens are indicated by an asterisk (*) with the locality number The river drainage tables also indicated the corresponding voucher catalog numbers and investigator field numbers that are listed in Appendix A Appendix A contains all the pertinent specific information regarding each of the localities such as the collector collector's field numbers which correspond to referenced field notes and the date of collection. The river tables identify the sites by a (+) in the column if the sampled populations were examined morphologically (MORPH) or genetically (DNA) If water analyses were performed at the site a (+) is used under the WATER column

In the genetic analysis two species outside the study area were used for comparative purposes Template DNA from *Elimia olivula* was provided by C. Lydeard from the University of Alabama at Tuscaloosa *E. olivula* is a species of the Coosa River, a tributary of the Upper Alabama River drainage system. *Pachychilus obeliscus* was used as an outgroup for this study *Pachychilus* is the only pleurocerid genus that occupies rivers in Central America The voucher specimens *Pachychilus*, have been deposited at FLMNH Specific information regarding these vouchers is located in Appendix A

Shell Morphological Analyses

Snails used in this study consisted of live collected material and catalogued material from designated museums Voucher specimens from all study sites have been deposited in the Florida Museum of Natural History Cataloged museum material is designated as such British Museum of Natural History BMNH Florida Museum of Natural History at University of Florida (UF) Museum of Comparative Zoology at Harvard University (MCZ) and University of Michigan Museum of Zoology (UMMZ)

Examination of Relevant Museum Types

The following type specimens were examined *Melania curvicostata* Reeve, 1861 Types BMNH 1994058 *Melania densicostata* Reeve 1861 Types BMNH 1994057 *Goniobasis doolyensis* Lea, 1862 Lectotype USNM 119121, Paralectotypes USNM 873108 *Goniobasis ellioti* Lea 1862 Lectotype USNM 119122 Paralectotypes USNM 873113 *Goniobasis etowahensis* Lea 1862 Lectotype USNM 121479 *Goniobasis gesneri* Lea 1868 Lectotype USNM 119134 *Goniobasis inclinans* Lea, 1862 Lectotype USNM 119743, Paralectotypes USNM 873102 *Goniobasis induta* Lea 1862 Lectotype USNM 11974 Paralectotypes USNM 873111 *Goniobasis inosculata* Lea 1862 Lectotype USNM 119177, Paralectotypes USNM 873115 *Melania modesta* Lea, 1845 Lectotype USNM 118186 *Goniobasis mutabilis* Lea 1862, Holotype USNM 118443 Paratypes USNM 118493 *Goniobasis mutabilis timidus* Goodrich 1942 Holotype UMMZ 486211 Paratypes UMMZ 49211 *Goniobasis ucheensis* Lea 1862 Lectotype USNM 1199259 Paralectotypes USNM 873110 *Goniobasis viennaensis* Lea 1862 Lectotype USNM 118743 Paralectotypes USNM 873110 The type material of *Goniobasis taitiana* Lea 1841 could not be located for this analysis

Shell Morphometrics

All shell specimens were examined for the following quantitative morphological characters total shell length (L), second shell length (2nd L) shell width (W) aperture height (ApH) aperture length (ApL) aperture width (ApW) number of whorls spire angle (A) number of ribs on the penultimate whorl (Ribs) position and number of spiral

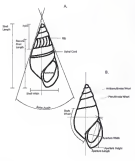

FIGURE 2. *Elimia* species and their distribution. A-B Quantitative shell features examined for morphological analysis C The study area consists of selected sites along the major river drainages of Florida Georgia and Alabama

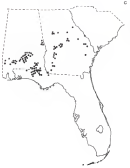

FIGURE 2– continued

cords on the body whorl (BW) and on the penultimate whorl of the spire (SpW), W/L, ApH/L, ApW/ApH, ApW/ApL, ApL/L, W/2ndL, ApW/W, and ApW/L (Figures 2A-B). However, preliminary results using factor and principal components analyses revealed that only twelve characters were informative in differentiating among the populations. The twelve variables used in this analysis were L, 2nd L, W, ApH, ApL, ApW, A, Ribs, BW, PW, W/2ndL, and ApW/ApH.

Shell measurements were made with a vernier caliper and measured to the nearest 0.1 mm. Aperture measurements were made using a micrometer and corrected to the nearest 0.1 mm.

Genetic Analysis

Mitochondrial DNA Isolation

Live adult snails were rinsed with distilled water to remove any loose debris. Snails were identified and measured for quantitative shell characters. Forceps were used to crack open the snail shells. Snails were then excised from the shell fragments. A portion of the foot or proboscis tissue was removed from each specimen. Extreme care was taken to avoid contamination with materials from the digestive gland. Laboratory instruments used in the preparation of tissue samples were washed after each specimen to avoid cross-contamination. Specimen samples were stored at -80°C.

Total genomic DNA was extracted from snail tissues using phenol-chloroform extraction (Hillis and Moritz 1992, 1996). The tissue samples were emulsified in 600-1000 µl of CTAB buffer in a glass hand-held tissue homogenizer (Fisher # HP 176-100). After the grinding process, no solid pieces remained within the tube. The buffer-tissue mixture produced a frothy slurry which indicated the endpoint of grinding. The addition of the PVP/βME buffer (10mM Tris-HCL, pH 8.0, 100 mM NaCl, 50 mM EDTA, 1% PVP, 0.2% βME) was a crucial step in the extraction process. This buffer removed mucous from the sample that could potentially (and often did) inhibit DNA amplification. Twenty microliters of 20% SDS (Sodium lauryl sulfate) was added to each mixture. The samples were then shaken vigorously to facilitate the reaction. The samples were incubated at 65°C in a water bath for at least 15 minutes. The tubes were removed from the water bath and allowed to cool before the next phenol extraction. Each tube was filled with 600 µl of phenol chloroform, shaken vigorously and spun in a microcentrifuge for 5 minutes. The supernatant was removed to a sterile tube. Each tube was then filled with 600 µl of chloroform, shaken vigorously, and spun in a microcentrifuge for 5 minutes. The samples were then treated with 10 µl of heat treated RNase (10 mg/ml) and incubated in a water bath at 35°C for 30 minutes to 1 hour. The samples were extracted again using phenol chloroform and chloroform. Fifty microliters of 3 M sodium acetate was added to each tube. The tubes were then filled with room temperature 95% ethanol. The tubes were incubated at room temperature for 5 to 10 minutes. For maximum recovery, tubes were allowed to incubate at -20°C overnight. Genomic DNA from successful isolations could be observed in each tube as stringy cottony white fibers floating in the liquid. The samples were spun in a microcentrifuge tube at room temperature for 5-15 minutes. The DNA pellet was washed with 70% ethanol and 95% ethanol (Kari, personal communication). The samples were then allowed to air dry by laying the tubes horizontally on a table top. The DNA was resuspended in 50 µl of TE (0.01 M Tris-HCL, pH 7.5, 0.001 M EDTA). The quantity of template DNA recovered from the samples was viewed with an agarose gel (1g agar with 100 ml of TE) containing 3 µl of ethidium bromide. Gels were visually inspected for template DNA using ultraviolet light.

Polymerase Chain Reaction (PCR) Methodology

Amplification of the cytochrome oxidase 1 gene segment (CO1) from the template DNA was conducted with a Polymerase Chain Reaction (PCR; Mullis and Faloona 1987). Modified versions of the primers developed by Folmer et al. (1991) were used for amplification. Primers developed for this study were CO5 (5'-GTTCAACAAATCATAAA-GATATTGG-3') and CO6 (5'-TAAACTTCAGGGTGACCAAA-AAATCA-3'). For each sample, the PCR mixture consisted of 3 µl of 3 mM $MgCl_2$, 26.5 µl sterile water, 5.8 µl 10x buffer, 8 µl of nucleotides, 2 µl of each primer, 0.5 µl of sterile bovine serum albumin, and 0.2 µl of *Taq* polymerase. The master mix was 48 µl. One to four microliters of the template DNA was added to each reaction mixture. Negative PCR controls consisting of template-free reactions were conducted to detect contamination and related problems. Samples were run for 36 cycles in a thermocycler at 50°C for annealing, 72°C for extension, and 94°C for denaturing. Five microliters of dye was added to 5 µl of each sample and loaded onto an agarose gel. DNA fragments of appropriate size were detected with ethidium bromide staining. A DNA mass ladder served as a size standard (Gibco BRL #10068-013). The gels were run at 115 V for approximately 30 minutes.

Agarose Gel Purification

Products from the PCR reaction were run out on an agarose gel stained with ethidium bromide to recover the target band. An aliquot of 4.5 microliters from each 50 µl PCR product was loaded onto an agarose gel. The gel was run between 10 and 14 hours at 20 V. Bands were excised out of agarose gel with a clean scalpel and placed in sterile dialysis tubing. Dialysis tubing was prepared by soaking in an aqueous sodium bicarbonate mixture (2 g of sodium bicarbonate and 100 ml of ultrapure water). The sodium bicarbonate solution with the soaking dialysis tubing was allowed to come to a rolling boil. The fluid was replaced by 100 ml of ultrapure water and allowed to come to a second rolling boil. Excess fluid was removed from the dialysis tubing and the excised gel fragments were inserted. Alligator clips were used to secure the ends and 250-650 µl of TE was added to each tube. Samples were placed in a gel rig and run for 40 to 60 minutes at 90 V. The dialysis bags were rotated where the gels were closet to the anode and 90 V was applied for 20 seconds. Each dialysis bag was re-examined under UV light to insure the removal of all the DNA within the gel. Samples were pipetted out of the dialysis bag and transferred to a 1.5 ml tube. PCR products were purified with a Millipore 30,000 MW filter.

DNA Sequencing

Sequencing reactions of the double-stranded DNA were conducted with primers with an automated sequencer (Applied Biosystems model 373A) at the University of Florida ICBR DNA Sequencing Core. A modified Sanger Method was used for DNA sequencing (Sanger et al., 1977).

Limnology

Water Collection

Limnological analyses of the riverine systems were performed on some of the collecting sites. Water temperature and dissolved oxygen were taken on-site where the snails were located. Temperature was measured in degrees Celsius using a small alcohol thermometer. The dissolved oxygen (DO) readings were performed with a Yellow Springs DO meter. Dissolved oxygen readings were adjusted for the water temperature measured by the thermometer. Dissolved oxygen was measured in parts per ohms

Collected water samples were stored in BOD glass bottles from these sites and transported back to the laboratory on ice. The BOD bottles were stored at 4°C in the laboratory until the analyses could be performed. The samples were analyzed the following week in the Department of Zoology, University of Florida.

Water Quality Analyses

The limnological assays that were performed in the laboratory were pH, specific conductivity, total dissolved solids, total alkalinity, and CO_2 acidity. Total dissolved solids, CO_2 acidity, and total alkalinity were measured by the methods of Welch (1948) and Clesceri et al. (1989). However, the methodologies are repeated below as they were performed on the samples. A portable Fisher pH meter was used to measure pH. Specific conductivity was measured in microS/cm using a Y-SCT meter (Yellow Springs Instrument). Total dissolved solids was measured by adding 50 ml of sample to a pre-weighed crucible. The water sample was evaporated in a drying oven at 200°F. The crucible was measured a second time. The difference between the initial and final mass was measured in grams and calculated as the total dissolved solids.

Total alkalinity was measured by performing a titration assay with 0.02N HCL. One hundred milliliters of sample water was placed in a clean Ehrlenmeyer flask. Two to three drops of methyl orange was added to each sample to serve as the indicator. The sample was titrated over a white surface to detect any subtle color changes. The 0.02 N HCl was titrated until the water solution turned a brassy pink color which indicated an endpoint at a pH of 4.5. Total alkalinity was calculated by the number of milliters of 0.02 N HCl multiplied by 1000 and divided by the milliters of sample used in each titration. Total alkalinity was expressed as mg/L of $CaCO_3$.

Carbon dioxide acidity (CO_2) was measured by performing a titration assay with 0.02N NaOH One hundred milliliters of sample water was placed in a clean Erlenmeyer flask. Two to three drops of phenolphthalein solution was added to the sample to serve as the indicator The sample was titrated over a white surface to detect any subtle color changes The 0.02 N NaOH was titrated til the water solution turned a brassy pink color which indicated the endpoint at a pH of 4.5 Total alkalinity was calculated by the number of milliliters of 0.02 N HCl multiplied by 1000 and divided by the milliliters of sample used in the titration. Carbon dioxide acidity (CO_2) was expressed as mg/L of $CaCO_3$.

Statistical Analyses

Statistical Analysis of Shell Characters

Univariate statistical analyses were calculated for the quantitative shell characters for the populations of smooth *Elimia* species that were sampled Multivariate statistical analysis were calculated for the ten *Elimia* populations indicated by (*+) in the MORPH column in TABLES 7-11 Only twelve of the eighteen shell variables were selected for the multivariate analysis Canonical discriminate analysis (CANDISC) of SAS was used to analyze the amount of variation among the populations. The Malahanobis distance matrix generated in the canonical discriminate analysis was used in the cluster analysis The CLUSTER procedure of SAS was used to evaluate the Malahanobis distance data. The cluster analysis used the furthest neighbor (COMPLETE) option

Statistical Analyses of the Mitochondrial DNA

The sequencing data were edited and aligned using Sequencher version 3.0 (Gene Codes Corp 1995) Several haplotypes were resequenced to insure the accuracy and reproducibility of the sequences   Sequence divergences between the haplotypes were estimated using the Kimura two parameter model (Kimura 1980) with the program package of PHYLIP 3.57 (Felsenstein 1993)   Evolutionary trees were generated using the branch-and-bound algorithm of PAUP and the neighbor-joining method (Saitou and Nei 1987) of PHYLIP   A rooted parsimony network was constructed using a Central American sister taxon *Pachychilus obeliscus* as the outgroup   Distance matrices were calculated using PAUP and PHYLIP (Felsenstein 1993)   A bootstrap confidence level of 100 replicates was used to support the nodes in the neighbor-joining and parsimony approach

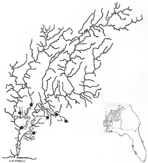

FIGURE 3 Localities sampled within the lower Alabama River drainage system. Dots indicate these sites. The numbers correspond to the specific locality information listed in Table 7

TABLE 7. Localities sampled within the lower Alabama River drainage system. Voucher numbers are given for each site. Locations that were not visited by the author are indicated as such (*). The categories of morphology (MORPH), water quality (WATER) and DNA are indicated in the upper right. A (+) in the column indicates that this site was analyzed for a particular assay. Some sites were only sampled for voucher specimens.

SITE NUMBER	SPECIFIC LOCALITY	VOUCHER SPECIMENS	MORPH	WATER	DNA
1	Alabama, Clarke Co., Branch of Rabbit Crk, 4.1 mi. W of Walker Spring	MCZ 236204	*+		
2	Alabama, Clarke Co., Fred T. Simpson Wildlife Refuge on Limestone Creek.	UF 258441		+	
3	Alabama, Clarke Co., spring run of Rabbit Creek on Hwy 10, 7.5 mi NE of Jackson.	UF 258442		+	+
4	Alabama, Monroe and Escambia Co. line, 0.8 mi. SE of Chrylser on the Little River.	NPF			
5	Alabama, Monroe Co., Mill Creek, 5 mi. WSW of Monroeville	UF 258435		+	
6	Alabama, Monroe Co., Limestone Creek, 2 mi. N of Drewry	UF 258433		+	
7	Alabama, Monroe Co., Limestone Creek, 2.6 mi. E of Drewry on SR 20	UF 258432		+	

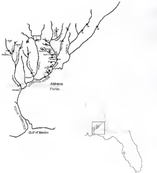

FIGURE 4 Localities sampled within the Escambia River drainage system Dots indicate these sites The numbers correspond to the specific locality information listed in Table 8

TABLE 8 Localities sampled within the Escambia River drainage system. Voucher numbers are given for each site. Locations that were not visited by the author are indicated as such (*). The categories of morphology (MORPH), water quality (WATER) and DNA are indicated in the upper right. A (+) in the column indicates that this site was analyzed for a particular assay. Some sites were only sampled for voucher specimens.

SITE NO#	SPECIFIC LOCALITY	VOUCHER SPECIMENS	MORPH	WATER	DNA
8	Alabama, Monroe Co., Escambia Cr. at Repton.	NPF			
9	Alabama, Monroe Co., Corley Cr. ca. 2 mi. E of Excel	NPF			
10	Alabama, Monroe Co. 2.5 mi. E of Goodway on Big Escambia Cr	NPF			
11	Alabama, Monroe Co., ca. 3.0 mi. E of Goodway on Corley Cr	NPF			
12	Alabama, Monroe Co. ca. 4.0 mi. SE of Goodway on Big Escambia Cr	NPF			
13	Alabama, Escambia, Big Escambia Cr. at Flomaton.	NPF			
14	Alabama, Conecuh Co., Debra McIntyre Spring at creek, 8.4 mi WSW of Evergreen	UF 258418 UF 258431		+	
15	Alabama, Escambia Co., at SR 29 on Burnt Corn Creek W of Brewton.	UF 224276 UF 241091			+
16	Alabama, Conecuh Co., Creek 2.2 mi. SW of Evergreen on US Hwy 31	UF 258430 UF 241092		+	
17	Alabama, Conecuh Co., Sepulga River at US Hwy 31	UF 224282			

TABLE 8--continued

SITE NO#	SPECIFIC LOCALITY	VOUCHER SPECIMENS	MORP	WATER	DNA
18	Alabama, Conecuh Co., creek, 7.5 mi E of Evergreen	UF 224285	+	+	
19	Alabama, Escambia Co., 20.3 mi E of Brewton	UF241084	+		
20	Alabama, Escambia Co., Smith Cr. nr Damascus	NPF			
21	Alabama, Conecuh Co., creek (Horton Branch)10 mi. NW of Brooklyn on SR 42	UF 241111	+		
22	Alabama, Conecuh Co., Rawls Creek, 4.7 mi. NW of Brooklyn on SR 42	UF 241109			
23	Alabama, Conecuh Co., Bottle Creek, 2.5 mi. NW of Brooklyn on SR 42	UF 241106	+		
24	Alabama, Escambia Co., Sepulga River at Brooklyn.	UF 224290	*+		
25	Alabama, Escambia Co., Amos Mill Creek on Sepulga River on SR 43, 1.1 mi. S of Brooklyn	UF 241103			
26	Alabama, Escambia Co., creek 5.3 mi. N of SR 43, Gin Creek, 2.2 mi. S. of Brooklyn	UF 241101			
27	Alabama, Escambia Co., small creek 6.4 mi. S of Brooklyn, trib. to Sepulga River	UF 224598	+		

TABLE 8--continued

SITE NO#	SPECIFIC LOCALITY	VOUCHER SPECIMENS	MORP	WATER	DNA
28	Alabama: Butler Co.: ca. 0.5 mi. E of Georgiana on Rocky Cr.	NPF			
29	Alabama: Conecuh Co.: Pigeon Cr. at US Hwy 84, ca. 18 mi. E of Evergreen	UF 224286	+	+	
30	Alabama: Butler Co.: Pigeon Creek, 10.7 mi. E of Georgiana	UF 224282			
31	Alabama: Crenshaw Co., 23.7 mi. W of Brantley on SR 106 on Patsaliga Cr.	UF 241074	+		
32	Alabama: Crenshaw Co., 11.8 mi. W of Brantley on Patsaliga Cr.	UF 241075	+		
33	Alabama: Crenshaw Co.: 3.5 mi. W of Rudledge on Patsaliga Cr. off SR 10	UF 241072	+		
34	Alabama: Pike Co., 7.1 mi. W of Troy on the Conecuh R.	NPF			

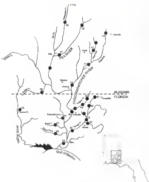

FIGURE 5 Localities sampled within the Choctawhatchee and Yellow River drainage systems. Dots indicate these sites. The numbers correspond to the specific locality information listed in Table 9.

TABLE 8 Localities sampled within the Choctawhatchee and Yellow River drainage systems Voucher numbers are given for each site Locations that were not visited by the author are indicated as such (*) The categories of morphology (MORPH) water quality (WATER) and DNA are indicated in the upper right. A (+) in the column indicates that this site was analyzed for a particular assay Some sites were only sampled for voucher specimens

SITE NUMBER	SPECIFIC LOCALITY	VOUCHER SPECIMENS	MORPH	WATER	DNA
35	Florida Okaloosa Co Murder Creek, trib to Yellow R	UF 241133	*+		+
36	Alabama Coffee Co Whitewater Creek at Lowry Mill, Coffee CR #60 22 mi S of Troy	UF 222568	+		
37	Alabama Coffee Co , 04 mi E of Elba on Pea River	UF 241076			
38	Alabama Geneva Co Corner Creek, 8 7 mi WSW of Samson at Hwy 54	UF 224297			
39	Alabama Barbour Co 5 3 mi W of Clio on Pea River	NPF			
40	Alabama, Geneva Co. Choctawhatchee River 0 5 mi E of Geneva	UF 251669	*+		+
41	Alabama Dale Co 9 0 mi S of Ozark	MCZ 98242	+		
42	Alabama Dale Co., 7 mi E of Ozark.	MCZ 98189	+		
43	Alabama Henry Co 6 0 mi W of Abbeville	MCZ 98173	+		
44	Holmes Co 0 1 E mi of Ponce de Leon on SR 90 at Jackson Spring	UF 41471 UF 224254		+	
45	Florida Walton Co N of Red Bay on Bruce Creek.	UF 224259		+	

TABLE 9--continued

SITE NUMBER	SPECIFIC LOCALITY	VOUCHER SPECIMENS	MORPH	WATER	DNA
46	Florida Walton Co 4 7 mi. S of Red Bay on SR 81 at Seven Run Creek.	NPF		+	
47	Florida Washington Co. 1 2 mi W of Ebro	UF 224243		+	
48	Florida Holmes Co 1 4 mi. W of Caryville on SR 90 Holmes Co Line on Choctawhatchee River	UF 224252		+	
49	Florida Holmes Co 8 7 mi N of Bonifay on SR 79 on Wrights Creek	UF 224343 UF 224244		+	
50	Florida Holmes Co , 0 7 mi E of Noma on SR 2 on Wrights Creek.	UF 224241 UF 224242	+	+	
51	Florida Jackson Co 1 mi W of Graceville in SR 2 of Holmes Creek.	UF 224239		+	+
52	Florida Holmes Co 4 3 mi E of Bonifay at Holmes Co line SR 90 on Holmes Creek	UF 224247		+	
53	Florida Washington Co Vernon 2-3 mi above Rt 79 bridge, spring run & adj to Holmes Co	UF 224184			
54	Florida Washington Co 08 mi N of Vernon on Holmes Creek (ELR019)	UF 224270		+	

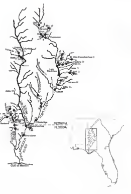

FIGURE 6 Localities sampled within the Apalachicola River drainage system. Dots indicate these sites. The numbers correspond to the specific locality information listed in Table 10

TABLE 10 Localities sampled within the Apalachicola River drainage system Voucher numbers are given for each site Locations that were not visited by the author are indicated as such (*) The categories of morphology (MORPH) water quality (WATER) and DNA are indicated in the upper right. A (+) in the column indicates that this site was analyzed for a particular assay Some sites were only sampled for voucher specimens

SITE NUMBER	SPECIFIC LOCALITY	VOUCHER SPECIMENS	MORP	WATER	DNA
55	Alabama Houston Co , 5.5 mi N of Cottonwood on Spring Cr	UF 241080			
56	Alabama Houston Co., 5 3 mi E of Campbellton on Spring Creek.	UF 241128			
57	Alabama Houston Co. 5 2 mi N of Cottonwood on SR 55 on tributary of Cowart's Cr	UF 241066			
58	Alabama, Houston Co 3 2 mi E of Madrid on Big Cr	UF 241080			
59	Florida Jackson Co spring run 2 9 mi NW of park entrance Blue Spring Hole Florida Caverns State Park.	UF 224230	+		
60	Florida Jackson Co small crk. 1 5 mi NW of park entrance Florida Caverns State Park on SR 166.	UF 224228	+		
61	Florida Jackson Co 1 4 mi N of Marianna on Chipola River off SR 166	UF 224235 UF 253357	+	+	
62	Florida, Jackson Co. Chipola R at Marianna	ELM132			
63	Florida Jackson Co 1 mi E of Merritt's Mill Pond	UF 224229		+	+
64	Florida Jackson Co Chipola River at SR 278	UF 253382			
65	Florida, Calhoun Co Chipola R at Clarksville	UF 251646	+		

TABLE 10 --continued

SITE NUMBER	SPECIFIC LOCALITY	VOUCHER SPECIMENS	MORP	WATER	DNA
75	Georgia, Baker Co., Ichawaynochawy Cr., ca. 2 mi. below Hwy. 91 bridge	UF 263095			
76	Georgia, Baker Co., Ichawaynochawy Cr., ca. 0.7 mi. above Flint R.	UF 263098			
77	Georgia, Dougherty Co., on Flint River in Albany	UF 251625		+	
78	Georgia, Crisp Co., Big Abrams Cr., 4.2 mi S of Oakfield	UF 251660 UF 251662 UF 251862	+ +		
79	Georgia, Crisp Co., Jones Cr., 2 mi. SE Oakfield	UF 251665 UF 251666	+ +		
80	Georgia, Crisp Co., North Branch of Swift Cr., 3.5 mi. W of Pateville	UF 251664			
81	Georgia, Crisp Co., Swift Cr., ca. 4 mi. E of Warwick.	UF 251656 UF 251658	+ +		
82	Georgia, Dooly Co., Limestone Cr. at McCay Rd., ca. 4 mi. S, 2 mi. E of Drayton.	UF 251651 UF 251653 UF 266250	+ +		
83	Georgia, Crisp Co., Limestone Cr. at Drayton Rd., 4.7 mi. S, 1.1 mi. E of Drayton	UF 251650		+	

TABLE 18 --continued

SITE NUMBER	SPECIFIC LOCALITY	VOUCHER SPECIMENS	MORP	WATER	DNA
85	Georgia, Dooly Co., Turkey Cr., 0.5 mi. S of Bryomville.	NPF			
86	Georgia, Dooly Co., Turkey Cr., 4.4 mi NNE, 0.6 mi E of Drayton	UF 251649			
87	Georgia, Dooly Co., Turkey Cr., 15.5 mi. NE of Bryomville				
88	Georgia, Dooly Co., Little Pennahatchee Cr. at McCay Rd	UF 230728 UF 241055	+		
89	Georgia, Upson Co., 7.1 mi. W of Thomaston on SR 36	UF 251611 UF 251612		+	
90	Georgia, Upson Co., 23 mi. W of Thomaston on Adams Perry Rd	UF 251615 UF 251614		+	
91	Georgia, Upson Co., at Po Biddy Rd. Bridge on the Flint R.	UF 251616			
92	Georgia, Upson Co., 5.6 mi. SW of Lincoln Park on SR 36 of Flint River (upstream shoal)	UF 241059 UF 241058			
93	Georgia, Upson Co., 5.8 mi. SW of Lincoln Park on SR 36 at Flint River (downstream shoal)	UF 241056 UF 241057			
94	Georgia, Meriwether Co., 4.6 mi. E of Gay on SR 109 on Flint River	UF 251617		+	

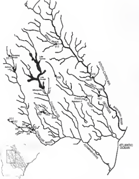

FIGURE 7 Localities sampled within the southern Atlantic Coastal river drainage systems Dots indicate these sites The numbers correspond to the specific locality information listed in Table 11.

TABLE 11 Localities sampled within the Atlantic coastal river drainage systems. Voucher numbers are given for each site Locations that were not visited by the author are indicated as such (*) The categories of morphology (MORPH) water quality (WATER) and DNA are indicated in the upper right. A (+) in the column indicates that this site was analyzed for a particular assay Some sites were only sampled for voucher specimens

SITE NUMBER	SPECIFIC LOCALITY	VOUCHER SPECIMENS	MORP	WATER	DNA
95	Georgia Butts Co. South River Snapping Shoals	UF 251609 UF 251667	*+		+
96	Georgia Dooley Co. Mock Spring 10 5 mi WSW 1 0 mi N of Hawkinsville	UF 268246 UF 268383		+	
97	Georgia Pulaski Co, Mile Cr 200-300 mi upstream from the Ocmulgee River ca. 1 mi SE of Hawkinsville	UF 268247 UF 263347 UF 268383	*+		
98	Georgia, Dooly Co Cedar Cr 10.5 mi WSW 1 mi N of Hawkinsville	UF 41455		+	
99	Georgia Pulaski Co Big Tuscawhatchee Cr 4 2 mi WSW of Hawkinsville on CR 257	UF 41453		+	
100	Georgia Pulaski Co. Big Tuscawhatchee Cr at Burnt Bridge Rd ca 7 mi W of Hawkinsville	UF 266328			
101	Georgia Pulaski Co spring seep of Big Tuscawhatchee Cr ca. 8 mi. WSW of Hawkinsville	UF 287264 UF 266330			
102	Georgia Laurens Co Rocky Cr 8 7 mi SE, 2 9 mi. NW of Dudley at SR 328	UF 41451	*+	+	
103	Georgia, Laurens Co Rocky Cr NW of Dexter, 1 3 mi S of Dudley on Hwy 338	UF 41452	+	+	

TABLE 11.—continued

SITE NUMBER	SPECIFIC LOCALITY	VOUCHER SPECIMENS	MORP	WATER	DNA
104	Georgia: Laurens Co., Rocky Cr., 5.1 mi. SE of Dudley at CR 338	UF 41450		+	
105	Georgia: Bulloch Co., ca. 4 mi. N of Statesboro on the Ogeechee River	UF 266248			
106	Georgia: Warren Co., Ogeechee River at Jewell.	UF 232373		+	
107	Georgia: Screven Co., Beaverdam Cr., 4.3 mi. NNE of Sylvania on Hwy 301	NPF		+	
108	Georgia: Screven Co., Brier Cr. on Hwy 301, 8 mi. NNE of Sylvania	NPF			+
109	Georgia: Columbia Co., 3 mi. NW of Augusta on the Savannah River	UF 41448 UF 263330		+	 +
110	Georgia: Elbert Co., Broad River, 5.1 mi. SW of Bowman	UF 231153 UF 231152			

CHAPTER 3
LABORATORY AND FIELD RESULTS

The analyses conducted for each of the major river drainages within the study region are summarized in Table 12. The results of the analyses are divided into five major sections; interspecific variation, intraspecific variation, examination of type specimens, species distribution, and limnological analysis.

Interspecific Variation of the Southeastern *Elimia*

Shell Morphological Analysis

Ten *Elimia* populations were used in the univariate and multivariate statistical analyses in differentiating among the taxa (APPENDIX B). Seven populations were species not associated with the complex. Three populations used in the analysis represented species not associated with the complex and were found outside of its range. These species were used as comparative material for the morphological and genetic analysis.

The results of the univariate analyses (ANOVA) showed that eleven of the twelve shell variables examined were significantly different from each other morphologically with a p value < 0.0001. However, the ratio W/2ndL was significantly different but only at a p value < 0.01 (Table 13). Although the p values were highly significant for all the variables, the variables measuring the number of ribs and the aperture ratio ApW/ApH had an ANOVA > 0.80. The ANOVA results indicated that these two variables were able to detect substantial differences among the ten populations.

TABLE 12. Summary of Analyses performed within the southeastern river systems. Sample sizes are included for each of the analyses performed in this study. The abbreviations used in the table are listed. CDA=Canonical Discriminant Analysis, Mitochondrial DNA Analyses. Water=Limnological Analyses.

RIVER DRAINAGE SYSTEM	CDA	POPULATION MORPHOLOGY	mtDNA	WATER
TOTAL SAMPLE SIZE	10	36	11	35
GULF COASTAL RIVERS	7	31	7	26
Lower Alabama River System	1	1	1	5
Escambia River System	1	7	1	3
Yellow River System	1	1	1	0
Choctawhatchee River System	1	6	2	8
Apalachicola River System	3	16	3	10
SOUTHERN ATLANTIC COASTAL RIVERS	3	5	4	9
Altamaha River System	3	5	3	8
Ogeechee River System	0	0	0	0
Savannah River System	0	0	1	1

The Canonical Discriminant Analysis (CDA) of the twelve shell morphological characters indicated that the first three canonical variables explained 96.5% of the variation among the ten populations (Table 14). The multivariate F test statistics of Wilk's Lambda, Pillai's Trace, Hotelling-Lawley Trace, and Roy's Greatest Root were highly significant with a p-value of <0.0001. The F test statistic scores indicated that the CDA was able to differentiate among the ten populations using the morphological characters measured in the analysis.

Three major assumptions are understood when utilizing CDA for classifying data-- the means are equal to 1, the variances are equal to 0, and the variables have no units of scale. Each canonical variable is primarily a measure of the differences between the standardized coefficients that are farthest from zero. Therefore, CAN 1 was determined by the three underlined variables in Table 15 (Aperture Height, Aperture Length, and the Ribs on the penultimate whorl). The variables CAN 2 and CAN 3 are indicated in the same manner (Table 15).

The results of the CDA are depicted by the needle graph in Figures 8A-B. The results of CAN 1 indicated that the larger the aperture height of the individual, the smaller the aperture length. Also, CAN 1 was determined by the number of ribs on the penultimate whorl. Individuals with the greatest number of ribs and the larger aperture the negative end of the CAN 1 axis have a lesser number of ribs on the penultimate whorl and a smaller aperture height.

The variable CAN 2 was influenced by the variables measuring Aperture Length, Aperture Width, and the aperture ratio, ApW/ApH. The results of CAN 2 showed that the larger the aperture length, the smaller the aperture width. The individuals at the positive end of the CAN 2 axis had a greater aperture ratio. The

Table 13 ANOVAS of the 12 Shell Characters

Shell Length	0.485528	0.0001
2nd Shell Length	0.594800	0.0001
Shell Width	0.633335	0.0001
Aperture Height	0.715026	0.0001
Aperture Length	0.637281	0.0001
Aperture Width	0.587281	0.0001
Penultimate Ribs	0.959352	0.0001
Body Whorl Spiral Chords	0.581627	0.0001
Spire Spiral Chords	0.721982	0.0001
Spire Angle	0.177992	0.0001
ApW/ApH	0.649258	0.0001
W/2ndL	0.105265	0.0107

Table 14 Results of the Canonical Discriminant Analysis

Canonical Variable	Canonical Correlation	Squared Canonical Correlation	Proportion of Variation Among Groups
1	0.984357	0.968859	0.6536
2	0.950851	0.904118	0.8511
3	0.919126	0.844793	0.9650

Table 15 Standardized Canonical Coefficients

Variable	CAN1	CAN2	CAN3
Shell Length	0.052	0.155	1.692
2nd Shell Length	0.033	0.422	1.225
Shell Width	-0.205	0.299	0.395
Aperture Height	1.321	-0.808	1.605
Aperture Length	-1.378	1.813	0.078
Aperture Width	0.204	-1.653	-0.890
Penultimate Ribs	0.878	0.453	-0.179
Body Whorl Spiral Chords	-0.005	0.036	-0.491
Spire Spiral Chords	-0.012	0.284	0.398
Spire Angle	0.0222	0.078	0.131
ApW/ApH	-0.336	0.864	0.312
W/2ndL	-0.017	-0.068	0.066

variable CAN 3 is determined by the total Shell Length, Second Shell Length, the Aperture Height, and the Aperture Width.

The results of CAN 3 indicated that the larger the second length and aperture height, the smaller the total Shell Length and the Aperture Width. The variable CAN 3 is represented by the height of the needle (Figure 8A). The taller the needle, the greater the value of CAN 3 for that observation.

The first three canonical variables for each of the individual observations are graphed in Figure 8A. The results show the individuals within each of the populations sampled cluster together except for *Elimia mutabilis*. However, the sample size consisted of only six adults which is reflected in the distribution of individuals within the graph.

Generalizations can be made regarding the morphological characteristics among the ten populations by using the population means (Figure 8B). The three-dimensional figure summarizing the data demonstrated that the taxa are differentiated by the shape of the aperture, the second length, and the number of ribs on the penultimate whorl (Figure 9B). The variable CAN 1 was characterized by the dimensions of the aperture and the number of penultimate ribs. According to the graph, *Elimia timida*, *E. curvicostata*, Yellow River *Elimia* species, *E. viennaensis*, and *E. mutabilis* have a larger aperture height than aperture length. Also, these species have a greater number of ribs of the penultimate whorl. *Elimia laitaina*, *E. ucheensis* and the populations from the Choctawhatchee, Altamaha, and Escambia have a smaller aperture height and a larger aperture length. These latter species also exhibit a lesser number of ribs on the penultimate whorl.

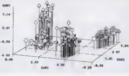

FIGURE 8. Canonical Discriminant Analysis of the southeastern *Elimia*. A. The variables CAN 1, CAN 2, and CAN 3 are plotted for each observation within the 10 populations. The populations are coded as such: Choctawhatchee River *Elimia* (♥) *E. laltana* Choctawhatchee River *Elimia* (☐) *E. curvicostata* (✯) *E. vanmaensis* (◆) Altamaha River *Elimia* (▲) Escambia River *Elimia* ( ) Yellow River *Elimia* (♀) *Elimia ucheensis* (♣), *E. timida* (●) and *E. mutabilis* (♦). B. The mean values of CAN1, CAN 2, and CAN 3 are plotted for the 10 populations.

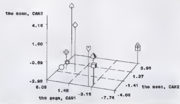

FIGURE 8B--continued

FIGURE 8C--continued

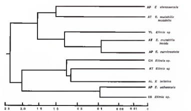

FIGURE 9C—continued

The southeastern *Elimia* can be also differentiated by the total Shell Length Second Length Aperture Height, and the Aperture Width The second length depicts the size of the penultimate whorl and the body Because the total length of the shell is typically subject to erosion the second length was used as a comparative measure of shell length

In summary generalizations can be made regarding the characteristics of each of the populations using morphometrics. The populations having the greatest number of ribs on the penultimate whorl were *Elimia timida* *E curvicostata* the Yellow River *Elimia* species *E viennaensis* and *E mutabilis* The other populations exhibited fewer ribs or may be devoid of ribs on the penultimate whorl

The morphometric analysis showed that the populations were also differentiated by the shape of the aperture using the ratio ApW/ApL. *Elimia ucheensis* and the Escambia *Elimia* species exhibited a high ApW/ApL. The remaining populations had a smaller ApW/ApL

Another differentiating factor among the populations was the size of the adult shells. The largest of the adult shells was *E viennaensis* and *E. mutabilis* The medium-sized adults consisted of populations representing *E lellaina*, *E ucheensis*, Yellow River *Elimia* species Atamaha River *Elimia* species, the Choctawhatchee River *Elimia* species, and Escambia River *Elimia* species The small-sized adults were *E timida* and *E curvicostata*

Cluster Analysis using Shell Morphology

A cluster analysis was performed on the Mahalanobis pairwise distance matrix among the 10 populations calculated by the CAD (Table 15) Using the cluster analysis data, the phenagram was generated by the furthest neighbor option. The phenagram is illustrated in Figure 8C.

The cluster analysis identified two major clades within the southeastern species. The first major clade included the Altamaha populations (*Elimia mutabilis*, *E. mutabilis timida*), the Apalachicola populations (*E. curvicostata*, *E. viennaensis*), and the Yellow River *Elimia*. This larger clade separated into three smaller clusters. Each smaller cluster represented the populations that were morphological similar to one another. The cluster diagram indicated that *E. mutabilis* and *E. viennaensis* are morphologically similar. The next morphologically similar group consisted of *E. curvicostata* and *E. mutabilis timida*. However, the morphological similarity of the Yellow River population clustered closest to *E. curvicostata*/*E. timida*.

The second major clade consisted of the Altamaha *Elimia*, the undescribed Escambia River *Elimia* and undescribed Choctawhatchee *Elimia*. Two smaller clusters were formed within this major clade. The Escambia River *Elimia* and *Elimia ucheensis* formed one cluster and *E. taitaina* and the Choctawhatchee River *Elimia* formed the other cluster. However, the Altamaha *Elimia* was morphological similar to the cluster containing *E. taitaina* and the Choctawhatchee *Elimia* species.

Table 16 Pairwise Distance Matrix for Cluster Analysis

0									
112 8	0								
61 65	16 63	0							
55 08	54 13	28 54	0						
83 84	211 8	178 2	145 2	0					
85 62	208 5	180 1	147 3	1 89	0				
143 1	61 72	45 11	30 36	213.6	216 03	0			
110 4	3 830	11 76	46 84	188 0	185 85	52 88	0		
11 34	114 8	75 23	48 38	86 28	100 81	131 99	109 11	0	
11 27	108 4	82 25	57 61	77 45	78 19	152 57	101 84	11 22	

According to earlier studies (Goodrich 1942, Clench and Turner 1956 Chambers 1990) the Escambia Yellow Choctawhatchee and Apalachicola populations were morphologically similar The results of this study indicate the contrary The above populations are morphologically distinct.

Goodrich classified pleurocerid species on the basis of qualitative shell characters Burch (1989) summarized Goodrich s classification (Table 5) Three species groups from Goodrich s classification were represented in this study which are *E boykiniana* group *E. carinocostata* group and *E mutabilis* group Goodrich considered *E uchеensis* and *E viennaensis* morphologically similar According to the cluster analysis the populations representing these species occupy two different major clades. Goodrich also described *E mutabilis timida* as a subspecies of *E. mutabilis* However these species occupy two separate clades Also Goodrich placed *E taitaina* within the *E mutabilis* group According to the cluster analysis, *E. taitaina* was placed outside the clade containing *E mutabilis*.

Analysis of Types

The type specimens for the species-complex, *Elimia curvicostata* were reviewed for quantitative and qualitative shell characters Appendix C lists the type species examined and their morphological measurements and statistics The type specimens are illustrated in Figures 9-23

The types designated as *Melania curvicostata* appeared most similar to *E curvicostata* However the 3 specimens of *M curvicostata* have very distinct incised spiral striations This sculpture pattern has not been found in any of the wild populations within the region It is unlikely that *M curvicostata* was found within the study area The next available name resembling the wild populations is *M. densicostata*

In this study several of the types were noted to be different age classes of *E densicostata* *Melania densicostata*, *Goniobasis doolyensis* and *Goniobasis induta* should be considered synonymous with *E densicostata*

Genetic Analysis of the Cytochrome oxidase subunit 1

Sequence Divergence

The aligned CO1 gene sequences yielded a fragment of 324 bp that was solved in all samples. The resulting sequences for 13 pleurocerid taxa are depicted in Figure 23 Each sequence represented mitochondrial DNA from a single individual This region of the DNA corresponded to the complement positions 974 and 1298 of *Drosophila yakuba* (Clary and Wolenstenholme 1985) The sequence comparison among the southeastern *Elimia* excluding the outgroup revealed 4 gaps 76 variable sites 33 transitions and 8 transversions Including the outgroup *Pachychilus* the sequence comparison revealed 4 gaps, 176 variable sites 94 transitions and 28 transversions These gaps within the gene segment will be further examined upon the sequencing of the complement strand from each individual

Pairwise percent sequence differences are summarized in Table 17 Maximum nucleotide divergence within populations of *Elimia curvicostata* was 3% Interspecific divergence among species ranged from 9-20% (*E curvicostata* vs Escambia *Elimia* B, *E timida* *E taitaina* *E bentoniensis* *E. dickinsoni* *E olivula* *E mutabilis*) Percent nucleotide divergence among pleurocerid genera was 27-36% (*Elimia* species vs. *Pachychilus obeliscus*)

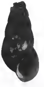

FIGURE 9 Shell of *Melania curvicostata* Reeve 1861 BMNH 1994056 lectotype Length = 17.4 mm

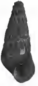

FIGURE 10 Shell of *Melania deniscostata* Reeve. 1861 BMNH 1994057 lectotype. Length = 18.0 mm

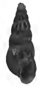

FIGURE 11 Shell of *Goniobasis doolyensis* Lea, 1862 USNM 119121 lectotype Length – 22.0 mm

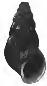

FIGURE 12 Shell of *Goniobasis elliotti* Lea, 1862 USNM 119122 lectotype. Length – 21.4 mm

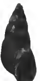

FIGURE 13 Shell of *Goniobasis etowahensis* Lea, 1862. USNM 121479 holotype. Length = 18.0 mm

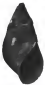

FIGURE 14 Shell of *Goniobasis gesneri* Lea 1868 USNM 119134 holotype Length = 18.0 mm.

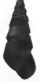

FIGURE 15 Shell of *Goniobasis inclinans* Lea 1862 USNM 118420 lectotype Length = 17.6 mm

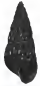

FIGURE 16 Shell of *Goniobasis induta* Lea 1862. USNM 119174 lectotype Length = 18.7 mm

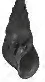

FIGURE 17. Shell of *Goniobasis inosculata* Lea, 1862. USNM 119177, lectotype. Length = 16.7 mm

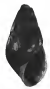

FIGURE 18. Shell of *Melania modesta* Lea, 1845. USNM 119189, holotype. Length = 15.0 mm

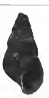

FIGURE 19 Shell of *Goniobasis mutabilis* Lea 1862 USNM 118443 holotype Length = 15.3 mm

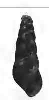

FIGURE 20 Shell of *Goniobasis mutabilis timidus* Goodrich 1942 UMMZ 49210 lectotype Length = 19.0 mm

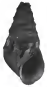

FIGURE 21 Shell of *Goniobasis ucheensis* Lea, 1862 USNM 119268 lectotype. Length = 12.9 mm

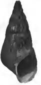

FIGURE 22 Shell of *Goniobasis viennaensis* Lea, 1862 USNM 118743, lectotype. Length = 21.8 mm

Genetic studies utilizing the CO1 gene for other invertebrate groups have yielded comparable results Nucleotide divergence among echinoderm species within the same genus was found to be 11-13% by Jacobs et al (1988) and 6-19% by Uehara and Shingaki (1985) However Baldwin et al (1997) determined that the nucleotide divergence within the family Penaeidae shrimp was 8-24%.

The number of nucleotide differences among the aligned sequences are given in Table 17 Intraspecific differences among the individuals from two populations of *E curvicostata* were a maximum of 11 base pairs Intraspecific differences among the two individuals of *Pachychilus obeliscus* from the same population were only 3 base pairs Interspecific differences among the species were found to be 28-47 base pairs However, the individuals representing the populations from the Choctawhachee *Escambia* and Yellow Rivers and *Elimia olivula* differ by only 3-7 bp The nucleotide divergence among the genera was 65-95 base pairs

Relationships of CO1 Genotypes

The analyses conducted by maximum parsimony and the neighbor joining methods gave identical phylogenetic trees The phylogenetic tree produced by maximum parsimony had a consistency index of 0 74 a retention index of 0 753 and a homoplasy index of 0 26 (Figure 23)

Using the outgroup *Pachychilus obeliscus* the phylogenetic tree indicated that the southeastern *Elimia* are divided into three distinct clades This node is supported by a high bootstrap of 100% The Altamaha species *E mutabilis* was distinguished from the 2 major clades of southeastern *Elimia* with a bootstrap value of 95% This relationship among the southeastern smooth morphological forms indicates that the species included 3 ancestral stocks

```
                 974                                                           1021
Chipola-curv    GTT GGT ATA AAA TAG GAT CGC CGC CCC CTG TAG GAT CGA AAA AAT G__
Apalach curv     C                  G                               -     G   A  TA
Choctawh R sp        A                          C   T           G    -        G  TA
Yellow R sp          A                          C   T           G    -        G  TA
Escambia R sp        A                      T   C   T           G    -        G  TA
Coosa-oliv           A                      T   C   T           G    -        G  TA
Altamaha-mut         G   NN                    CG    T CT       GG  TC        G  TA
Altamaha tim         A                      T       G       G   G    -G       A  TA
Alabama-tait                                T   A   T                -        G  TA
Choctawha-dks                               T   T   T           G    -        A  TA
Savannah-bent                               A   A   T           G    -        A  TA
Pachychilus     TGC TGA TA   GG ATT GA  TCT CT    T C   GCT GG  TC    G   T  CT
Pachychilus     TGC TGA TA   GG ATT GA  TCT CT    T C   GCT GG  TC    G   T  CT

                 1022                                                          1069
Chipola-curv    GTA TTA AAA TTT CGA TCT GTT AAA AGC ATT GTA ATA GCA CCG GCT AAG
Apalach curv
Choctawh R sp    G                       C       T                              GA
Yellow R sp      G                       C       T                              GA
Escambia R sp    G                       C       T                              GA
Coosa-oliv       G                               T                              GA
Altamaha-mut     G                               T                              GA
Altamaha-tim     G                                                T  A           A
Alabama tait     G                               T                G  T
```

FIGURE 23 Aligned mtDNA Sequences of the Cytochrome Oxidase subunit I of the southeastern *Elimia*. Comparative sequences consisted of 342 bp Cytochrome oxidase subunit I for 12 *Elimia* taxa and an outgroup species (*Pachychilus obeliscus*). The species abbreviations are as follows: curv=*E. curvicostata* oliv=*E. olivula* mut=*E. mutabilis mutabilis* tim=*E. m. timida* tait=*E. taitiana* dks=*E. dickinsoni* bent=*E. bentoniensis*. Dashes correspond to gaps and the N s are missing data

```
Choctawha-dks                               T  AT           G   G   A
Savannah-bent                               G   T   G               C       A
Pachychilus             G   C       C           T   C       T   C   C      GC
Pachychilus             G   C       C           T   C   A   T   C  TC      GC

              1070                                                            1115
Chipola-curv  ACG GGA AGT GAT AAT AAA AGA AGA ATT GCT GTA ATT TTT ACG GAT CAA
Apalach-curv
Choctawh R sp   A       C               G                           A
Yellow R sp     A       C               G                           A
Escambia R sp   A       C               G                           A
Coosa-oliv      A       C               G                           A
Altamaha-mut    A       C               G                       C   A
Altamaha-tim    A       C          G            C
Alabama-tait    A       C           C   G                   C       A       G
Choctawha-dks   A   C  A       G            G                       A       G
Savannah-bent   A           A  G        G                           A
Pachychilus     T                  GT  A        C               A   A
Pachychilus     T                  GT  A        C               A   A

              1116                                                            1163
Chipola-curv  ACA AAT AAA GGT AGA CGT TCA AAC TGT ATA CCT CGT CAT CGT ATA TTA
Apalach curv                                          G           C
Choctawh R sp                  AT           T           C   C
Yellow R sp                    AT           T           C   C
Escambia R sp                  AT           T           C   C
Coosa-oliv                     AT           T           C   C
Altamaha-mut                   AT           T       G   C
Altamaha-tim                   A    C                   C
Alabama tait        C  GG      AT   C       T
Choctawha dks                  AG           T           C
Savannah-bent   G       G      AC           T           C
```

FIGURE 23--continued

```
Pachychilus       G   C       C  AT   C   G   T   C   T   A       C
Pachychilus       G   C       C  AT   C   G   T   C   T   A       C

                1164                                                              1211
Chipola curv    ATA ATA GTA GTA ATA AAA TTT ACA GCA CCT AAA ATA GAA GAT GCA CCG
Apalach-curv
Choctawh R sp                     G   G                       T   G       C
Yellow R sp                       G   G                  G    T   G       C
Escambia R sp                     G   G                       T   G       C
Coosa-eliv                        G                           T   G       C
Altamaha-mut                      G   G                       T   G       C
Altamaha-tim                                                              C
Alabama-tait                     G   G       G                       C   C   T
Choctawha-dks                                                             T   A
Savannah bent                         G       T
Pachychilus               T               A   G                       A A     A
Pachychilus               T               A   G                       A A     A

                1212                                                              1260
Chipola-curv    GCT ACA TGG AGC GAA AAG ATT GCT AAA TCT ACA GAA CCT CCT GCG TGA
Apalach-curv                                      G
Choctawh R sp        AG       T           C      G                        A
Yellow R sp          AG       T           C      G                        A
Escambia R sp        AG       T           C      G                        A
Coosa-oliv           AG       T           C      G                        A
Altamaha-mut         AG       T                  G                        A
Altamaha-tim        AG                       C   G               G           C
Alabama-tait        A    T  A                   G           .        C   A
Choctawha dks             A
Savannah-bent        A        A                       C       C   G       A
Pachychilus          AG   T  AA       A   A       G   C   T   T   C   A   A
Pachychilus          AG   T  AA       A   A       G   C   T   T   C   A   A
```

FIGURE 23–continued

```
              1261                                         1298
Chipola-curv  GCT AAG TTC CTA GCT AGT GGT GGG TAA ACA GTT CAT
Apalach curv                                          C
Choctawh R sp      GA   T          A    G
Yellow R sp        GA   T          A    G   A
Escambia R sp      GA   T     C    AN   G   G
Coosa-oliv         GA   T          AC   G
Altamaha-mut        A   T          A    G   A
Altamaha-tim       G    T          A
Alabama-tait    C  G    T          A        A
Choctawha dkw      G    T   T       C   C   A
Savannah-bent      GA   A               G   A
Pachychilus     G  GA   A  CC      A    G   A   T
Pachychilus     G  GA   A  CC      A    G   A   T
```

FIGURE 23--continued

According to the phylogenetic tree, the *Elimia curvicostata* species-complex includes two major clades The first major clade is observed in the Florida Gulf Coastal *Elimia* which included the Choctawhatchee *Escambia* and Yellow Rivers This cladewas affiliated with *E olivula* of the Alabama River with a bootstrap value of 100% Within this clade the relationship among the Gulf Coastal river drainages is supported by very low bootstrap values of 55 and 66 The relationship remains merely speculative until this can be clarified These values may improve by examing a longer DNA sequence strand

The second major clade of the complex consists of *Elimia curvicostata* E. *dickinsoni*, and *E. limida* The node separating *E dickinsoni* is supported by a low bootstrap value of 38% This relationship remains speculative The two populations of *E curvicostata* segregate out with a high bootstrap value of 100

The relationship between *E curvicostata* and *E mutabilis limida* is supported by a bootstrap value of 78% This relationship indicates that *E limida* of the Altamaha River is more closely related to *E curvicostata* than *E mutabilis mutabilis* This is contrary to studies by Goodrich (1942) who had placed *E limida* as a subspecies of *E mutabilis*

Intraspecific Variation of the Southeastern *Elimia*

Shell Morphological Analysis

Thirty-five *Elimia* populations of species were measured for 12 morphological characters within the study area. The means and standard deviations are indicated for each of the population measured (Table 16) The most variable shell characters were the dimensions measuring Length (L) 2nd Length (2nd L) and the spire angle The population means for these characters were typically greater than 2 0 standard

TABLE 17 Sequence divergences are given above the diagonal of the matrix. Below the diagonal, base pair differences are given. The species abbreviations are as follows: *curv=E. curvicostata, oliv=E. olivula, mut=E. m. mutabilis, tim=E. m. timida, tait=E. taitiana, dks=E. dickinsoni, bent=E. bentoniensis, Pach=Pachychilus*. The abbreviations for the river drainages are as follows: CP Chipola, AP=Apalachicola, CH=Choctawhatchee, ES=Escambia, AL=Alabama, AT=Altamaha, S=Savannah

	CP-*curv*	AP-*curv*	CH	YL	ES	AL-*oliv*	AT-*mut*	AT-*tim*	AL *tait*	CH-*dks*	S-*bent*	*Pach*	*Pach*
CP-*curv*	0	0.03	0.12	0.12	0.13	0.12	0.20	0.09	0.14	0.14	0.12	0.36	0.36
AP-*curv*	11	0	0.14	0.15	0.15	0.14	0.20	0.11	0.17	0.14	0.15	0.36	0.36
CH	36	41	0	0.006	0.006	0.013	0.11	0.11	0.11	0.14	0.11	0.36	0.37
YL	40	43	3	0	0.01	0.019	0.11	0.12	0.11	0.14	0.11	0.36	0.37
ES	42	42	5	8	0	0.008	0.01	0.11	0.11	0.13	0.11	0.37	0.37
AL-*oliv*	36	37	4	7	3	0	0.11	0.11	0.11	0.12	0.12	0.36	0.37
AT-*mut*	47	47	20	23	23	22	0	0.20	0.18	0.22	0.18	0.26	0.27
AT-*tim*	31	39	31	34	34	30	46	0	0.14	0.13	0.14	0.36	0.37
AL *tait*	44	44	32	34	37	34	45	48	0	0.13	0.13	0.35	0.36
CH-*dks*	36	34	35	39	39	37	52	36	33	0	0.12	0.36	0.38
S-*bent*	28	34	32	33	36	35	45	36	40	34	0	0.36	0.37
Pach	94	90	88	90	85	86	75	91	94	95	86	0	0.003
Pach	93	91	92	93	93	91	85	93	94	95	85	3	0

FIGURE 24 Phylogenetic Relationships between the smooth sculptured *Elimia* species in the southeastern river drainages. Maximum parsimony was used to generate a tree between the thirteen pleurocerid taxa. The analysis consisted of six species--*E. bentoniensis, E. dickinsoni, E. olivula, E. mutabilis mutabilis, E. m. timida*. Five populations from the Apalachicola, Chipola, Choctawhatchee, Escambia, and Yellow Rivers represented the species-complex. The outgroup used in this analysis was *Pachychilus obeliscus* from Honduras. Each node is represented by a bootstrap value. Bootstrap values > 50% are significant.

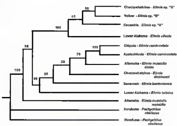
58
60
100
95
100
100
76
39
59
88
Choctawhatchee - *Elimia* sp. "B"
Yellow - *Elimia* sp. "B"
Escambia - *Elimia* sp. "A"
Lower Alabama - *Elimia olivula*
Chipola - *Elimia curvicostata*
Apalachicola - *Elimia curvicostata*
Altamaha - *Elimia mutabilis timida*
Choctawhatchee - *Elimia dickinsoni*
Savannah - *Elimia boykiniana*
Lower Alabama - *Elimia taitiana*
Altamaha - *Elimia mutabilis mutabilis*
Honduras - *Pachychilus obeliscus*
Honduras - *Pachychilus obeliscus*

FIGURE 24. Phylogenetic Relationships among the smooth *Elimia* species in the southeastern river drainages

TABLE 18. Morphological Characteristics of the southeastern *Elimia*. A. A survey of populations within the region. The variable L, 2nd L, W, ApH, ApL, ApW are measured in millimeters. The variable Angle is measured in degrees. The quantity was noted for the number of Ribs, spiral chords on the BW (Body Whorl) and SpW (Penultimate whorl of the Spire). The species identification and sample size (n) are indicated for each locality site. The mean (x) and standard deviation (sd) are listed for each measured variable in the sample. B. The minimum and maximum values for each measured variable are given for each species. For the known species, the types are listed below. The same quantitative information is also indicated for the types.

Drainage	Species		L	2nd L	W	ApH	ApL	ApW	Ribs	BW	SpW	Angle	W/2ndL	ApW/ApH
AL 1 (n=25)	*E. taitaina*	x	14.4	12.1	7.2	5.9	6.6	3.8	0.2	0.10	0.10	43.7	0.60	0.66
		sd	2.2	2.0	2.1	0.7	0.9	0.9	0.8	0.40	0.30	7.1	0.10	0.05
ES-16 (n=15)	*Elimia* sp. "A"	x	16.4	13.4	7.1	4.3	7.2	3.6	0.0	2.40	1.10	36.2	0.51	0.90
		sd	2.9	1.7	0.8	0.5	1.0	0.0	1.0	0.90	0.60	8.8	0.08	0.09
ES-18 (n=23)	*Elimia* sp. "A"	x	15.9	13.1	7.3	5.1	7.4	4.0	0.0	0.00	0.90	40.4	0.55	0.80
		sd	1.3	1.1	0.4	0.5	0.6	0.4	0.0	0.20	0.90	3.4	0.08	0.12
ES-19 (n=20)	*Elimia* sp. "A"	x	12.6	11.2	6.4	4.0	6.9	3.8	0.0	0.20	0.20	35.9	0.58	0.87
		sd	1.9	1.3	0.8	0.4	0.7	0.4	0.5	0.00	0.40	3.5	0.07	0.08
ES-21 (n=19)	*Elimia* sp. "A"	x	17.9	13.7	7.7	5.0	7.9	4.2	2.8	0.40	0.80	34.8	0.54	0.84
		sd	1.3	0.9	0.4	0.8	0.3	0.3	6.5	1.00	0.70	5.2	0.06	0.08
ES-23 (n=13)	*Elimia* sp. "A"	x	19.8	15.4	8.2	4.8	8.2	4.2	1.0	0.50	0.70	37.8	0.53	0.97
		sd	2.3	1.8	0.8	0.6	0.9	0.5	3.8	0.70	1.10	5.5	0.02	0.08
ES-31 (n=6)	*Elimia* sp. "A"	x	23.7	18.7	9.9	6.7	9.7	5.0	10.9	1.30	0.50	35.1	0.53	0.78
		sd	2.3	1.6	1.1	0.4	0.9	0.5	8.1	0.80	0.50	4.6	0.03	0.08
ES-32 (n=2)	*Elimia* sp. "A"	x	23.1	17.8	9.1	5.9	9.8	5.2	10.5	0.00	2.00	37.5	0.51	0.88
		sd	3.4	1.9	1.8	0.3	0.8	0.7	0.5	0.00	1.00	4.8	0.03	0.07

TABLE 16(1)—continued

Drainage	Species		L	2nd L	W	ApH	ApL	ApW	Ribs	8W	SpW	Angle	W/2ndL	ApW/ApH
ES-33	*Elmis* sp "A"	x	21.8	17.1	8.0	8.1	9.5	4.8	13.7	0.00	1.00	38.2	0.53	0.94
(n=3)		sd	0.8	1.1	0.5	0.3	0.4	0.5	0.8	0.00	0.00	2.2	0.01	0.04
YL-35	*Elmis* sp "B"	x	15.1	12.6	6.8	6.7	7.3	3.7	11.8	0.50	0.60	39.8	0.57	0.65
(n=12)		sd	3.1	3.0	1.0	1.1	1.2	0.6	1.5	1.00	0.80	5.9	0.04	0.03
CH-36	*Elmis* sp "B"	x	18.0	13.4	7.6	4.6	7.9	4.0	2.4	0.90	0.70	41.7	0.57	0.81
(n=14)		sd	2.0	1.5	0.8	0.6	0.6	0.5	5.2	1.40	0.90	8.1	0.02	0.07
CH-40	*Elmis* sp "B"	x	15.4	13.7	7.7	7.1	7.6	3.6	0.0	0.70	0.50	39.5	0.57	0.55
(n=21)		sd	3.5	3.2	1.3	1.4	1.5	0.8	0.0	1.10	0.50	11.8	0.07	0.04
CH-41	*Elmis* sp "B"	x	12.7	10.8	6.1	5.1	6.0	3.5	1.5	1.00	0.50	38.8	0.59	0.69
(n=4)		sd	2.5	2.8	0.6	0.6	0.9	0.4	2.6	1.00	0.50	5.6	0.06	0.03
CH-42	*Elmis* sp "B"	x	14.8	12.1	7.0	5.9	6.6	2.8	0.0	1.60	1.30	37.0	0.58	0.66
(n=25)		sd	2.7	2.3	1.0	1.6	1.2	0.6	0.0	1.10	0.40	4.8	0.04	0.06
CH-43	*Elmis* sp "B"	x	17.5	14.6	7.8	6.1	7.1	4.4	16.0	0.80	2.10	34.3	0.56	0.72
(n=6)		sd	1.6	1.8	0.8	0.8	0.5	0.4	0.8	0.60	1.30	5.3	0.05	0.04
CH-44	*E.* "*curvicostata*"	x	16.8	13.5	7.4	6.1	7.0	3.8	11.6	0.00	0.60	30.8	0.55	0.62
(n=5)	*densicostata*	sd	2.3	1.2	0.4	0.5	5.6	0.4	3.5	0.00	0.60	8.2	0.14	0.18
AP-60	*E.* "*curvicostata*"	x	17.8	13.6	7.5	7.0	7.8	3.6	13.0	0.10	0.00	41.4	0.54	0.57
(n=7)	*densicostata*	sd	2.0	1.4	0.5	0.6	0.7	0.3	0.5	0.30	0.00	5.3	0.03	0.05
AP-61	*E.* "*curvicostata*"	x	13.6	10.8	5.9	5.3	5.6	3.3	13.3	0.10	0.20	30.6	0.54	0.61
(n=25)	*densicostata*	sd	1.3	0.8	0.4	0.5	0.4	0.2	1.9	0.30	0.50	4.2	0.04	0.06

TABLE 16(1)--continued

Drainage	Species		L	2nd L	W	ApH	ApL	ApW	Ribs	BW	SpW	Angle	W/2ndL	ApW/ApH
AP-70	*E. viennaensis*	x	14.8	12.1	7.1	5.8	7.2	3.7	9.4	3.80	2.20	48.3	0.58	0.57
(n=23)		sd	1.3	1.2	0.5	0.6	0.6	0.3	5.3	0.90	0.60	5.9	0.03	0.03
AP 71	*E. ucheensis*	x	15.1	12.5	7.3	6.9	4.1	3.7	0.0	2.40	1.04	36.2	0.58	0.53
(n=24)		sd	1.3	1.0	0.8	0.5	0.9	0.4	0.0	0.80	0.20	9.7	0.03	0.80
AP 72	*E. ucheensis*	x	15.2	12.6	9.5	5.9	6.9	3.7	0.9	1.00	0.84	34.4	0.52	0.64
(n=29)		sd	2.9	2.1	0.9	0.9	0.9	0.6	3.1	0.95	0.83	5.5	0.04	0.08
AP 78	*E. "curvicostata"*	x	13.3	10.4	5.9	5.0	5.6	3.0	13.9	0.30	0.36	32.9	0.58	0.59
(n=18)	*densicostata*	sd	2.0	1.3	0.9	0.7	0.7	0.3	2.3	0.70	0.90	7.2	0.04	0.05
AP 78	*E. viennaensis*	x	14.2	12.9	7.5	9.5	7.0	3.7	19.1	9.30	3.60	42.3	0.60	0.57
(n=12)		sd	1.5	1.3	0.7	0.9	0.7	0.3	2.3	2.90	1.00	4.9	0.03	0.03
AP 79	*E. "curvicostata"*	x	12.4	9.6	5.9	9.1	5.1	2.8	13.6	0.30	0.04	34.1	0.59	0.55
(n=29)	*densicostata*	sd	1.5	1.2	0.5	0.8	0.9	0.3	1.6	0.70	0.20	6.0	0.04	0.04
AP-79	*E. viennaensis*	x	13.8	11.6	7.3	9.1	9.9	3.9	19.5	5.00	3.00	46.9	0.62	0.60
(n=21)		sd	0.7	0.8	0.4	0.4	0.4	0.3	1.7	2.80	0.90	5.4	0.07	0.04
AP-81	*E. "curvicostata"*	x	15.8	12	8.7	5.9	6.9	3.5	13.2	0.10	0.10	33.9	0.56	0.61
(n=10)	*densicostata*	sd	2.8	1.7	0.9	0.7	0.8	0.9	6.9	0.30	0.30	7.1	0.02	0.03
AP-81	*E. viennaensis*	x	19.4	19.3	9.1	9.1	9.1	4.9	12.5	9.60	3.10	40.3	0.56	0.66
(n=12)		sd	1.9	1.7	0.6	1.9	1.0	0.6	1.1	2.70	1.20	4.6	0.02	0.21
AP-83	*E. viennaensis*	x	20.3	17.5	9.8	8.5	9.6	5.0	14.6	9.80	3.40	38.6	0.58	0.58
(n=25)		sd	1.5	1.1	0.8	0.9	0.9	0.4	1.8	3.00	1.10	7.4	0.06	0.03

TABLE 18-1--continued

Drainage	Species		L	2nd L	W	ApH	ApL	ApW	Ribs	BW	SpW	Angle	W/2ndL	ApW/ApH
AP-85	*E "curvicostata"*	x	13.2	10.3	5.5	4.9	5.4	3.0	13.9	1.60	1.00	34.4	0.52	0.63
(n=24)	*densicostata*	sd	1.7	1.4	0.9	0.6	0.6	0.3	1.9	1.30	0.50	5.3	0.10	0.04
AP-85	*E. viennaensis*	x	19.1	16.5	9.3	8.3	9.4	4.9	14.2	4.20	3.80	34.6	0.57	0.59
(n=17)		sd	1.4	1.1	0.6	0.6	0.5	0.4	3.8	2.50	0.90	4.4	0.03	0.03
AP-86	*E. viennaensis*	x	20.2	17.1	9.9	9.1	9.2	9.4	12.0	3.00	1.50	38.5	0.58	1.06
(n=2)		sd	1.0	0.3	0.2	0.1	0.9	0.7	1.0	0.00	0.50	2.5	0.00	0.10
AP-88	*E. viennaensis*	x	20.1	17.2	9.8	9.4	9.8	4.7	15.3	1.00	0.60	35.8	0.59	0.57
(n=26)		sd	2.2	1.9	0.9	0.9	0.8	0.8	0.4	1.30	1.30	4.2	0.05	0.03
AT-95	*E. mutabilis*	x	19.9	17	9.7	8.8	9.2	5	9.2	4.30	1.50	40.8	0.57	0.59
(n=6)		sd	2.7	2.4	1	1.3	1.1	0.7	4.3	2.60	0.80	4.5	0.03	0.02
AT-96	*E. timida*	x	10.0	8.0	4.3	4.3	4.1	2.9	15.2	1.00	1.30	30.7	0.55	0.67
(n=22)		sd	0.8	0.8	0.9	0.3	0.4	0.3	4.1	0.00	0.40	5.9	0.03	0.06
AT-97	*E. timida*	x	13.9	9.7	9.9	5.0	5.2	3.0	13.7	1.00	1.30	38.1	0.57	0.60
(n=22)		sd	1.2	9.7	0.5	0.5	0.6	0.3	1.7	0.40	0.40	2.9	0.04	0.05
AT 102	*Elimia sp.* "C"	x	11.8	9.7	5.8	5.0	5.6	3.1	0.0	3.80	1.00	43.1	0.60	0.63
(n=15)		sd	4.9	3.8	1.6	1.9	2.2	0.9	0.0	2.30	0.40	4.2	0.06	0.05
AT 103	*Elimia sp.* "C"	x	17.4	15.0	8.9	7.3	9.0	4.4	4.8	2.80	2.00	43.8	0.58	0.60
(n=22)		sd	2.0	1.9	0.9	0.9	0.7	0.5	9.3	2.40	1.20	5.9	0.07	0.04

TABLE 15(2)—continued

SPECIES	N	L	2ND L	W	ApH	ApL	ApW	Ribs	BW	SpW	Angle	W/2ndL	ApW/ApH
Elimia densicostata	115	7.2-22.2	6.3-16.3	4.1-8.4	3.0-8.1	3.9-8.1	2.3-7.0	0-7	0-8	0-3	17-48.5	0.61-0.88	0.48-0.89
Melania densicostata	3	15.2-18.5	10.8-12.7	8.3-8.8	5.4-5.7	4.5-8.6	3.8-4.2	16-17	6	6	26.0-32.0	0.51-0.58	0.70-0.76
Goniobasis doolyensis	34	7.6-22.0	5.6-15.0	3.7-8.4	3.2-7.0	3.4-7.7	1.8-4.3	0-19	0-4	0-1	22.8-63.0	0.51-0.70	0.47-0.89
Goniobasis induta	42	8.0-18.7	5.8-14.0	3.8-7.7	3.4-6.6	3.1-7.1	2.2-4.8	10-17	0-8	0-3	38.5-48.0	0.44-0.78	0.48-0.75
Elimia mutabilis	6	18.0-22.8	13.9-20.0	7.8-10.5	8.8-10.0	7.4-10.7	3.0-8.0	0-10	1-7	1-3	33.5-48.0	0.53-0.63	0.24-0.27
Goniobasis mutabilis	22	13.8-18.5	11.3-18.0	8.7-8.5	3.2-8.0	4.5-8.0	2.0-4.8	0-14	2-8	1-2	21.0-24.3	0.53-0.63	0.30-0.89
Elimia timida	44	8.5-13.2	8.0-8.7	3.2-8.1	3.3-5.8	3.9-5.2	2.1-3.7	0-22	1	1-2	23.0-45.0	0.43-0.80	0.48-0.90
Goniobasis mutabilis timidus	35	13.0-20.4	9.7-14.8	5.0-7.8	4.7-8.8	4.9-6.7	4.7-6.0	0	0-3	0	18.0-28.0	0.47-0.58	0.48-0.89
Elimia ucheensis	49	7.2-18.3	6.3-16.1	4.3-8.9	2.8-8.8	5.8-6.2	2.3-4.0	0-8	0-8	0-3	34.4-38.2	0.52-0.89	0.53-0.83
Goniobasis ucheensis	27	5.8-12.8	5.8-10.7	3.9-8.1	2.9-7.0	3.9-8.7	1.6-4.2	3-6	0-8	0-3	29.6-48.5	0.53-0.73	0.43-0.99
Elimia viennaensis	82	13.2-23.7	10-19.3	8.4-9.5	3.0-8.7	4.3-19.7	3.3-11.1	16-22	0-14	0-11	29.0-56.8	0.30-0.80	0.81-1.21
Goniobasis viennaensis	3	18.8-21.8	13.7-16.7	7.7-8.5	4.8-8.7	7.4-8.7	4.1-5.1	0-14	0-8	0-1	28.5-48.0	0.56-0.58	0.53-0.55
UNDESCRIBED SPECIES													
Altamaha *Elimia* sp. D	37	6.8-21.3	5.3-18.2	3.0-8.0	2.9-8.6	3.2-9.8	1.9-5.9	0-14	0-8	0-3	35-57.5	0.27-0.73	0.54-0.68
Choctawhatchee *Elimia* sp. B	81	8.4-23.2	6.2-20	4.2-10.1	3.8-8.5	3.9-8.7	2.1-5.0	0-19	0-8	0-8	17.0-65.5	0.48-0.82	0.45-1.02
Escambia *Elimia* sp. A	83	12.3-28.1	8.8-19.8	8.0-11.8	3.4-7.9	8.4-11.3	2.0-8.0	0-19	0-8	0-4	27-49.5	0.48-0.80	0.66-1.09

deviations. The other shell dimensions measured in the populations such as Width (W), Aperture Width (ApW), Aperture Height (ApH), Aperture Length (ApL), W/2nd L and ApW/ApH were 1.0 standard deviation from the mean. An exception was noted for the mean measuring Width (W) for *E. mutabilis* (AT-85). The standard deviation for the mean was only slightly above 2.0.

The sculpture characters that quantified the number of spiral chords and ribs varied intraspecifically and interspecifically. Higher mean values for this character were indicated for *E. viennaensis*, *E. mutabilis*, *E. ucheensis* and an Altamaha *Elimia* species. Lower mean values for this character were found in *Elimia taitaina*, Escambia *Elimia* species, *Elimia curvicostata*, *E. timida*. Intraspecies variation was greatest for *E. viennaensis*, *E. mutabilis*, and Altamaha *Elimia* species regarding the number of spiral chords located on the body whorl. This character was highly variable in 5 of the 7 populations of *E. viennaensis* that were quantified (AP-78, AP-79, AP-81, AP-83, AP-85). Because only a few individuals of *E. mutabilis* (AT-95) could be measured, the sample size was not an adequate representation of this species. However, intraspecies variation was also high for this character in Altamaha *Elimia* species (AT-102, n=15, AT-103, n=22) which had an adequate sample size.

The number of spiral chords on the penultimate whorl was the least variable intraspecifically. All populations, regardless of species, were within 1.5 standard deviations of the mean. However, the greatest number of spiral chords of the penultimate whorl appeared on *E. viennanesis*. The lower mean values for spiral chords were for Escambia *Elimia* species and *E. curvicostata*.

The number of ribs varied within and among the species groups. In Escambia *Elimia* species (ES-19, ES-23, ES-31), Choctawhatchee *Elimia* species (CH-36, CH-41), *E. mutabilis* (AT-95), *E. timida* (AT-96, AT-97), and Altamaha *Elimia* species (AT-103), the number of ribs were highly variable In *Elimia curvicostata* (CH-44, AP-78, AP-79 AP-85), *E. ucheensis* (AP-72) *E. viennaensis* (AP-70 AP-78 AP-79) were somewhat variable The number of ribs is not a reliable character in differentiating among species.

The results show that the southeastern *Elimia* exhibit a high degree of intraspecific variability of certain shell characters such as spire angle and the number of ribs and spiral chords The findings on intraspecific variability are similar to the morphological results of other studies on *Elimia* species (Chambers 1981, Dillion and Davis 1980) Similar morphological results regarding the variability of the spire angle and shell sculpture have also been demonstrated in other pleurocerid species (Chesium and Mouzon, 1934 Davis 1969 Dillion and Davis 1980 Dillion 1984)

Species and their Geographic Distribution

The smooth sculptured *Elimia* species within each of the river drainages are morphologically and genetically distinct. Each species is restricted to a single river drainage system except for *E. densicostata* (=*E. curvicostata*) which inhabits the Flint and Chipola Rivers and their tributaries of the Apalachicola River system Also this species inhabits the lower end of the Choctawhatchee River and its tributaries in Florida which include Holmes and Wrights Creeks

Other species inhabiting the Apalachicola River drainage are *Elimia dickinsoni*, E. *ucheensis* and *E. viennaensis* *Elimia dickinsoni* occurs the lower Choctawhatchee River and its tributaries in Florida. Also this species is found within the Chipola River and its tributaries *Elimia ucheensis* is confined to the Uchee Creek system of the Chattahoochee River *Elimia viennaensis* is confined to the Flint River and its tributaries

Two undescribed species were found within the Alabama headwaters of the Florida Gulf Coastal rivers One species is located in the Escambia River system and is identified as *Elimia* species "A" The other species is found in the upper Choctawhatchee River and its tributaries in Alabama This species is identified as *Elimia* species "B"

Three smooth sculptured *Elimia* species are found within the Altamaha River system of eastern Georgia *Elimia mutabilis* and an undescribed species *Elimia* species "C" were found in the headwaters of the Oconee *Elimia timida* was found in the headwaters of the Ocmulgee River

Limnological Analyses

Water quality analyses were performed at thirty-two locations inhabited by *Elimia* within the study region Temperature conductivity dissolved oxygen, acidity alkalinity pH, and dissolved solids were recorded for each site The specific measurements exact locality information and the time of year the measurements were taken are listed in Appendix D The limnological conditions are summarized for each species addressed within this study (Table 19)

Water temperature varied within the streams surveyed *Elimia* were found in streams with temperatures ranging from 12-25°C Other studies have reported similar temperature ranges from streams inhabited by *Elimia* During a yearly survey of a tributary of the Cahawba River system in Alabama Ross and Ultsch (1980) recorded *E cahawbensis* and *E. carinifera* occupying streams with a temperature range from 12-24°C Their study also showed that certain sites within a single tributary remained near a constant temperature year round Other sites within the same tributary fluctuated between extreme temperatures Ross and Ultsch's study (1980) demonstrated that the chemical and physical conditions within a single stream are not homogenous Another study conducted by Blair and Sickel (1986) surveyed *Elimia* (=*Goniobasis*) *laqueata* in the Tennessee and Cumberland Rivers during the summer months. Their results indicated the snails were occupying tributaries at cooler temperatures (15-19°C).

Conductivity values pertaining to sites inhabited by *Elimia* were divided into four categories--high, moderate, low, and variable. High conductivity readings were recorded from streams inhabited with *E. postelli*, *Elimia* species "A", and *E. timida*. The higher conductivity values (> 100microS/cm) were also indicative of springs. Some populations of *E. densicostata*, *Elimia* species "A", *E. taitaina*, *E. timida*, and *E. postelli* were found near springs. However, their distribution was not limited to springs. Low to moderate conductivity values (30-85 microS/cm) were recorded for *E. bentoniensis*, *E. clenchi*, *E. dickinsoni*, *E. mutabilis*, *Elimia* species "C", *E. ucheensis*, and *E. viennaensis*. Conductivity values that were found to be highly variable in streams inhabited by *E. densicostata*, *Elimia* species "A", and *E. taitaina*.

Dissolved oxygen (DO) was found to vary within the streams inhabited by *Elimia* within the region. Species found in streams with lower levels of DO (6-8.5 ppm) were *E. clenchi* and *E. dickinsoni*. *Elimia mutabilis* and *E. viennaensis* were recorded from streams with moderate DO readings (8-9.5 ppm). Higher DO levels (greater than 10 ppm) were noted in streams inhabited by *E. bentoniensis*, *E. postelli*, *Elimia* species "A", *Elimia* species "C", *E. taitaina*, and *E. ucheensis*. *Elimia densicostata* was recorded in streams with the most variable range of DO values. Because DO is required for aerobic respiration, it is one of the more important factors dictating the snail

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fauna within a water body However Ross and Ultsch (1980) discovered that DO levels within a stream fluctuated throughout the year Also the lower DO levels were reported from streams during the winter months

Other studies measuring the DO levels of streams inhabited by *Elimia* have revealed similar results in their analyses. Ross and Ultsch (1980) recorded DO from 5 to 12 ppm in Tennessee streams inhabited by *Elimia* Dazo (1965) recorded DO levels ranging from 17 63 to 53 86 ppm in areas within the Great Lakes region populated by *Elimia*

Acidity levels recorded from the streams within the region ranged from low to variable depending on the species Low acidity values (0-20 mg/L CaCO3) were recorded in tributaries occupied by *E bentonensis* *E clenchi*, *E. densicostata*, *E. mutabilis* *E fimide* and *E ucheensis* An acidity value of 0 mg/L (Table 19) indicated the stream had a pH greater than 8.3 Streams occupied by *E postelli* *Elimia* species "A" *Elimia* species "C" and *E taitsina* were shown to be highly variable in their acidity levels Acidity measurements were not reported within the other *Elimia* studies

Alkalinity levels varied among the *Elimia* species surveyed Low levels of alkalinity (< 40 mg/L CaCO3) were noted from tributaries inhabited by *E bentoniensis* *Elimia* species "C", *E ucheensis* and *E viennaensis*. Moderate levels of alkalinity (40-60 mg/L CaCO3) were recorded from streams inhabited by *E clenchi* and *E dickinsoni* The alkalinity analyzed from streams inhabited by *E densicostata* *Elimia* species "A" and *E taitsina* were highly variable

Similar alkalinity levels were reported from northern Alabama streams by Huryn et al. (1994) ranging from 17-111 mg/L CaCO3 Also Blair and Sickel (1980) recorded alkalinity levels at concentrations greater than 60 mg/L CaCO3 for tributaries of the Cumberland and Tennessee Rivers occupied by *Elimia (=Goniobasis)* Their study took place during a single season from May to September On the contrary Shoup (1943) recorded alkalinity concentrations from 5-220 mg/L CaCO3 within the Tennessee and Cumberland Rivers populated by *Elimia* (=*Goniobasis*) Shoup s results were taken during the summer months within a four year period

The pH of rivers was also measured at each location. Stream pH ranged from 5.95 -8 84 The site with the lowest pH was found in a tributary of the Sepulga River inhabited by *Elimia* species "A" The locality site with the highest pH measured within this analysis was recorded for *E densicostata* (pH 8 3) in Merritt's Mill Pond, a spring-fed pond of the Chipola River Other studies have reported similar pH levels of streams inhabited by *Elimia* Dazo (1965) recorded *Elimia* (=*Goniobasis*) from tributaries within the Great Lakes region having a pH range of 7.5-8 8 Houp (1981) recovered *Pleurocera* another pleurocerid genus living in Kentucky streams with a pH of 6.8 to 7 1

Dissolved solids were measured from all water samples. The results from the water samples ranged from low to high The highest amount of dissolved solids were recovered from sites inhabited by *Elimia postelli* (0 34 g) and *E timida* (0 35 g) within the Altamaha River system Moderate amounts of dissolved solids (0 14 g) were recovered from the lower Choctawhatchee River inhabited by *E. clenchi* The lowest amount of dissolved solids was reported from streams populated by *E densicostata*, *E dickinsoni*, *Elimia* species "A", *Elimia* species "C", *E tallaina* and *E uchеensis*. No dissolved solids were measured from the locations inhabited by *E bentoniensis* and *E. mutabilis*

TABLE 18 Summary of limnological analyses associated with *Elimia* species The following abbreviations are used N=Sample Number TEMP=temperature COND=Conductivity DO=Dissolved Oxygen

SPECIES	N	TEMP (oC)	COND (microS/cm)	DO (ppm)	ACIDITY mg/l $CaCO_3$	ALKALINITY (mg/l $CaCO_3$)	pH	DISSOLVED SOLIDS (g)
E bentoniensis	1	*23	*61 5	*12	*4	*28	*6 45	*0
E clenchi	2	15-17	30-32	5 1-8 1	4	24-52	6 52-6 74	0-0 14
E. densicostata	6	13-24	40-214	5-16 3	0-8	24-116	6 5-8 84	0-0 06
E. dickinsoni	2	16-18	80-87	5 8-6.2	6	24-56	6 89-7 25	0-0 05
E mutabilis	1	*19 5	*50	*8	*6	*52	*7 69	*0
E. postelli	3	16-21	126-171.2	9 5-15 3	4-16	32-56	7 08-7 61	0-0 34
Elimia species *	3	20-25	102.2-395	9 8-12.9	0-20	42 156	5 95-7 03	0-0 01
Elimia species *	3	17-17 5	43-92	16 3-17 5	4-16	32-36	7 02-7 16	0-0 05
E taitsina	5	20-24	44-353	10 8-16 4	2-14	28-144	7.4-7 67	0-0 05
E timida	2	20-23	*196 6	11 5-14 5	*4	*112	*7 77	*0 35
E. ucheensis	3	12-13	36 1-45 1	0 06-11	2	16-36	6 84-6.98	0-0 01
E. viennaensis	3	17-17 5	40-60	8.8-9 4	0-8	32-40	7 71-8 13	0-0.07

An asterisk (*) indicates the results are based on a single water sample

CHAPTER 4
SYSTEMATICS

Goodrich proposed the currently accepted classification of *Elimia* The species of *Elimia* (=*Goniobasis*) were segregated into 21 species groups on the basis of ornamental shell sculpture (Goodrich 1934b 1934c, 1935a, 1935b 1937b 1938, 1941 1942 1944 Burch 1982 1989) He facilitated this scheme by selecting a single sculpture feature that was shared by species that had the same morphological state However, the criterion of morphological state was over simplified within the groups

Elimia curvicostata was assigned to the "*carinocostata*" species group by Goodrich (1942) on the basis of having plicate (vertical ribs) shell sculpture Members of the "*carinocostata*" group include *E carinocostata E bentonensis E indula E curvicostata* and *E dickinsoni* (Goodrich 1934c, 1941 1942, 1944, Clench and Turner 1956 Burch 1989)

The geographic distributions of the species groups within Goodrich s classification system were also disparate The distribution of the five species within the "*carinocostata*" species group occupy three different river drainages. *Elimia carinocostata and E bentoniensis* occur in the Coosa River system outside of the area of this study A current investigation of this group by F G Thompson indicates that these two species are not related to *E curvicostata* and have different juvenile shell morphologies *Elimia dickinsoni* and *E* "*curvicostata*" inhabit the lower tributaries of the

Choctawhatchee and Chipola Rivers of the Apalachicola River drainage system. According to the literature (Goodrich 1942, Burch 1982, 1989), *Elimia induta* inhabits the Flint River tributaries of the Apalachicola River drainage system.

The *mutabilis* species group is also addressed in this study. This group is relevant because Goodrich referred to the populations from the Choctawhatchee and Escambia Rivers as *Elimia mutabilis*. The "*mutabilis*" group consisted of *E. mutabilis mutabilis*, *E. mutabilis timidus*, and *E. taitiana*. Goodrich grouped these species together because of their numerous shell striae (spiral striations) and similar obese shell shape. With this species-group, he also disregarded their distributions.

The results of this study confirm that there is not a morphological or genetic basis for the affinities of the species that Goodrich placed in the "*carinocostata*" or the "*mutabilis*" species groups. The approach of the present study is to review the taxonomic names of the species related to *Elimia "curvicostata"* as defined by earlier authors. Shell morphological characters of the type specimens will be discussed and how the types compare to the current populations within the Gulf Coastal drainage system.

Overview of the Gulf Coastal fauna

This study demonstrates that the name, *Melania curvicostata* Reeve 1861, has been misapplied to the species found within the Gulf Coastal drainages. None of the population samples from the region resemble the three syntype specimens. A close examination of the three individuals comprising the type series of *M. curvicostata* indicates that an important feature of the shell sculpture that was overlooked or omitted from the original description by Reeve (1859-1861) and by subsequent authors. Also the figured specimen in Reeve (1861) is generalized and does not appear to be any of the three specimens in the type series. The distinctive feature consists of numerous incised spiral striations that are clearly noticeable in the three syntypes This sculpture is characteristic only to populations of the species group, *Elimia edgariana*, occurring in the Tennessee-Ohio River drainage system

The next available name within the literature that most closely resembles the populations within the Gulf Coastal region is *Melania densicostata* Reeve 1861, originally described from "Florida" This name has been considered a synonym of "*curvicostata*" by Tryon (1863-1865 1873) and subsequent authors Populations strongly resembling the types of "*densicostata*" are found within the Chipola and Flint Rivers of the Apalachicola River drainage system The type locality for "*densicostata*" is here restricted to the Chipola River at Marianne, Florida Marianna is a long established Florida city dating back to when "*densicostata*" was described This town was situated on the only major road in western Florida at that time

This investigation also recognizes as two synonyms of the name *Elimia densicostata*–*Goniobasis induta* Lea 1862b and *Goniobasis doolyensis* Lea 1862b Both of these species were described from tributaries of the Flint River near Vienna Georgia Careful analysis of the *G induta* and *G doolyensis* indicate that they are based on different age classes of the species *E densicostata*

Goniobasis elliotti Lea 1862b *G gesneri* Lea 1868b, *G inosculata* Lea 1862b *G inclinans* Lea 1862b *G ucheensis* Lea 1862b, and *Melania modesta* Lea 1845 are clearly not synonyms of *Elimia curvicostata* *Goniobasis inclinans* resembles *E. floridensis* which is found in the St. Johns River and Gulf Coastal rivers of Florida. Contrary to allocations by Chambers (1990)the remaining names belong to the species-group, *E. boykiniana* of the Chattahoochee River and not closely related to *E densicostata* The "*curvicostata*" complex also contained *E viennaensis*, a species restricted to upper Flint River and its tributaries within the Apalachicola River drainage system *Elimia viennaensis* is morphological and genetically distinct and is recognized as a separate species (unpublished data)

In conclusion, five species of this species-complex occupy the Gulf Coastal river drainages These are *Elimia densicostata* *E dickinsoni* E. *viennaensis* and two undescribed species (Table 20). The Flint River species *E induta* and *E. doolyensis*, recognized as distinct species by Goodrich (1942) and Burch (1982, 1989) appear to be populations of *E densicostata* *Elimia dickinsoni* is a distinct species and genetically related to *E densicostata* In addition *E timida* from the Altamaha River system is also a member of this species group

Synopses of the Gulf Coastal Rivers Species

Elimia densicostata (Reeve 1861)

UNIQUE FEATURES –*Lateral profile of the spire is convex in outline Columella is straight to slightly convex in frontal view The first post-embryonic whorl has a strong carina located above the periphery Ribs begin on the 3rd juvenile whorl. The width of the ribs is strong and pronounced (similar to* E. viennaensis*)*

ADULT SHELL (Figure 10) –The periostracum varies from olive green dark brown to golden brown Some populations have banded shells The color of the bands range from dark to reddish brown. The shape of the shell is elongate-conical. The length of the adult shell ranges from 7 2-19 5 mm The apex of the shell is eroded from most individuals The remaining number of whorls varies from 3-7 In lateral profile the spire is slightly convex. The suture between the whorls is deeply impressed, but there is little indication of a shoulder below the suture The macrosculpture consists of carinae vertical ribs spiral chords and longitudinally growth striations The vertical ribs extend across the whorl ending at the suture There are 10-17 vertical ribs on the penultimate whorl. The ribs vary from being straight to slightly retrocurved. The width of the ribs are strong and pronounced. The width between the ribs varies. Thin spiral chords exist at or above the periphery of whorls of the spire. The number of spiral chords on the penultimate whorl varies from 1-3. Additional spiral chords exist at, above, or below the periphery of the body whorl. The number of spiral chords on the body whorl varies from 1-7. Incremental growth striations are apparent on all the whorls. Some individuals lack spiral chords. Also, earlier whorls have decussate striations similar to a checker board pattern. The aperture is ovate in shape. In lateral view, the outer lip is slightly curved. The base of the aperture extends as a tongue-like protrusion. The columella may be straight or slightly convex in frontal view and convex in lateral view. At the bottom of the aperture, the basal lip is slightly reflected downward.

JUVENILE SHELL.–The embryonic whorls are eroded from most specimens. The first post-embryonic whorl has a strong carina or keel located at the top of the whorl. This carina drops to below the periphery in the remainder of the whorls. The first three apical whorls have a pitted but glossy appearance. Carinae on the later whorls becomes spiral chords. Ribs may appear on the third whorl. Decussate sculpture becomes apparent on the third whorl.

TABLE 20 Review of the taxonomic names associated with *Elimia densicostata*. A ( ) indicates that the author did not address this taxonomic name

SPECIES NAMES	TRYON, JR.	GOODRICH	CLENCH & TURNER	BURCH	CHAMBERS	MIHALCIK
acturata Haldeman 1862	*mutabilis*	*boykiniana* *viennaensis*		( )	( )	( )
symmetrica Haldeman 1841	*ucheensis*			*symmetrica*		
modesta Lea 1862	–		*catenoides*	( )	*boykiniana*	*gerhardti* group *boykiniana* group
bipartita Reeve 1860	*bipartita*	*curvicostata*				
curvicostata Reeve 1861	*curvicostata*	*curvicostata*	*curvicostata*	*curvicostata*	*curvicostata*	*curvicostata*
densicostata Reeve 1861	*curvicostata*	*curvicostata*	*curvicostata*		*curvicostata*	*densicostata*
canbyi Lea 1862	*etowahensis*	*catenaria* *cancellata*	*floridensis*		*curvicostata*	*floridensis* group
doolyensis Lea 1862	*doolyensis*	*curvicostata*	*curvicostata*		*curvicostata*	*densicostata*
elliottii Lea 1862	*elliottii*	*boykiniana* *viennaensis*	*curvicostata*		*curvicostata*	*boykiniana* group
etowahensis Lea 1862	*etowahensis*	*catenaria* *cancellata*			*curvicostata*	*boykiniana* group
inclinans Lea 1862	*inclinans*	*catenaria* *inclinans*	*curvicostata*	*catenaria* *inclinans*	*floridensis*	*floridensis* group
induta Lea 1862	*doolyensis*	*induta*	*curvicostata*	*induta*	*curvicostata*	*curvicostata*
cancellata Lea 1862	*pallescens*				*curvicostata*	*boykiniana* group
mutabilis Lea 1862	*mutabilis*	*mutabilis* *mutabilis*		*mutabilis* *mutabilis*	–	*mutabilis*
furtum Lea 1862		*boykiniana* *viennaensis*	*curvicostata*		–	*boykiniana* group
ucheensis Lea 1862	*ucheensis*	*ucheensis*	*curvicostata*	*ucheensis*	*curvicostata*	*boykiniana* group
viennaensis Lea 1862	*viennaensis*	*boykiniana* *viennaensis*	*viennaensis*	*boykiniana* *viennaensis*	*curvicostata*	*viennaensis*
gesneri Lea 1862	*gesneri*	*ucheensis*	*curvicostata*	–	*boykiniana*	*boykiniana* group
mutabilis timidus Goodrich 1942		*mutabilis* *timidus*		*mutabilis* *timidus*		*timida*
dickinsoni Clench & Turner 1956	–		*dickinsoni*	*dickinsoni*	*dickinsoni*	*dickinsoni*
		curvicostata	*curvicostata*	*curvicostata*	*curvicostata*	*Elimia* n. sp. "A" MS
	–	*curvicostata*	*curvicostata*	*curvicostata*	*curvicostata*	*Elimia* n. sp. "B" MS
–		*mutabilis*	( )	*mutabilis*		*Elimia* n. sp. "C" MS

MATERIAL EXAMINED.--The material examined is listed in Appendix A.

DISTRIBUTION.--The species is found in the Chipola River and its tributaries. It is also found in the tributaries of the Apalachicola River in Florida, and in the tributaries of the lower Flint River in Georgia.

HABITAT.--Snails are found burrowing through sand and silt and attached to limestone substrata, aquatic vegetation, river debris, rocks, and bridge pilings. The tributaries vary in size from 3-50 meters in width in a moderately fast current. The water may be clear or stained light brown by tannins.

Elimia dickinsoni (Clench and Turner, 1956)

UNIQUE FEATURES.--*Ribs are extremely fine and retrocurved. Ribs originate and terminate at the sutures. In lateral profile, the spire is slightly convex to straight. In frontal view, a distinct parietal callus is apparent. In lateral view the outer lip is reflected. At the fourth post-embryonic whorl, an undulating spiral chord develops above the periphery.*

ADULT SHELL. (Figure 25)--The periostracum may be olive green to golden brown. Some populations have banded shells. A single yellow band when present lies below the suture. Occasionally, other dark brown bands may be present. The shape of the shell is elongate-conical. The length of adult shells range from 22.2-29.0 mm. The apex is often eroded from most individuals. The remaining number of whorls varies from 6-8. In lateral profile, the spire is very slightly convex to straight. The suture between the whorls is well-defined. However, there is little indication of a shoulder below the suture. The macrosculpture consists of carinae, ribs, spiral chords, and growth striations. Some populations are devoid of ribs. When present, the ribs are extremely fine and retrocurved. The ribs originate and terminate at the sutures. The width between the ribs is one-fourth the length of the rib. Spiral chords on the penultimate whorl range from 2-5. These chords exist at, above, or below the periphery. Spiral chords on the body whorl range from 1-9 and are located at, above or below the periphery. Growth striations are apparent on all the whorls. The aperture is ovate in shape. In lateral view the outer lip is slightly curved and reflected. In the frontal view, a distinct parietal callus is apparent. The columella is moderately convex or straight. The base of the aperture extends forward as a tongue-like projection.

JUVENILE WHORLS.--The embryonic whorls are eroded from most specimens. A carina develops at the periphery of the second post-embryonic whorl. At the fourth, an undulating spiral chord develops above the periphery. Also, the initial carina migrates below the periphery. Two carina appear below the periphery on the fifth whorl with the same undulating appearance. Ribs appear between the fourth and sixth whorl.

MATERIAL EXAMINED.--The material examined is listed in Appendix A.

DISTRIBUTION.--This species inhabits the tributaries of the Choctawhatchee River in Florida including Holmes Creek and Wrights Creek. It is also found in the Chipola River and its tributaries.

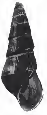

FIGURE 25. Adult shell of *Elimia dickinsoni* (Lea, 1862) UF 25457

HABITAT --Snails were found crawling through sand and silt or attached to limestone substrata, aquatic plants, river debris, rocks, or bridge pilings. The streams ranged from 3-30 meters in width. This species occupies streams ranging from a slow to a moderately fast current. The water was clear or stained brown.

Elimia viennaensis (Lea 1862)

UNIQUE FEATURES.--*Carina on post-embryonic whorl located below the periphery. Ribs appear on the fifth post-embryonic whorl (similar to* Elimia *species "A"). Two carinae appear on the third whorl. In frontal view, the columella is moderately convex or straight and is thickened near its base. Ribs are strong and pronounced (similar to E. densicostata).*

ADULT SHELL (Figure 22).--The periostracum may be olive green or dark brown to golden brown. Some populations have banded shells. The color of the bands ranges from dark red to reddish brown. The shape of the shell is elongate-conical. The length of adult shells ranges from 10.9-22.4 mm. The apex is often eroded from most individuals. The remaining number of whorls varies from 4 to 7. In lateral profile, the spire is slightly convex in outline. The suture between the whorls is well-defined. However there is little indication of a shoulder below the suture. The macrosculpture consists of carinae, ribs, spiral chords, and growth striations. The penultimate whorl has 10 to 22 ribs. The ribs are strong, pronounced, and retrocurved. Spiral chords on the penultimate whorl range from 1-5. These chords exist at, above, or below the periphery of the penultimate whorl. Spiral chords on the body whorl range from 3-11. Some individuals lack spiral chords on the spire and body whorl. Growth striations are apparent on all the whorls. There is a faint hint of decussate striations on the earlier whorls. The aperture is elliptical in shape. In lateral view the outer lip is slightly curved (in the figured specimen, the lip is slightly fractured, the longitudinal growth striations best indicate the direction of the curvature). In the frontal view, the columella is moderately convex or straight and is thickened near its base. In the sub-adults, the aperture is ovate in shape. The base of the aperture extends forward as a tongue-like projection.

JUVENILE WHORLS.--The embryonic whorls are eroded from most specimens. The first post-embryonic whorl has a strong carina or keel located below the periphery of the whorl. Two carinae appear on the third whorl. The first three apical whorls have a pitted appearance. This condition is apparent until the sixth whorl. Carinae on the later whorls becomes spiral chords. Ribs appear on the fifth whorl. Decussate sculpture becomes apparent on the third whorl.

MATERIAL EXAMINED.--The material examined is listed in Appendix A.

DISTRIBUTION.--The species is found in the upper Flint River and its tributaries.

HABITAT.--Snails were found burrowing through sand and silt, and also found attached to river debris, rocks, and bridge pilings. Stream width was from 8-100 meters with a moderately fast current. The water was clear or stained light brown.

Elimia species "A" MS, new species

UNIQUE FEATURES.–*All adult shells are banded with the first band being yellow and the second band being reddish-brown. The first post-embryonic whorl has a strong carina or keel located below the periphery of the whorl. Adult shells typically lack ribs; the aperture is slightly concave in lateral profile. Ribs are low and retrocurved.*

ADULT SHELL (Figures 26A, B).–The periostracum ranges from dark brown to golden brown. Most individuals have banded shells. These bands are also visible on the parietal wall of the aperture. The color of the bands range from dark red to reddish brown. All specimens have two distinct bands that appear below the suture. The first band is yellow and the second band is a reddish-brown. The shape of the shell is elongate-conical. The length of the adult shell is from 13.6-28.1 mm. The length is 4 to 7 whorls. In lateral profile the spire is slightly convex in outline. The suture between the whorls is well-defined. There is little indication of a shoulder. The macrosculpture consists of carinae, ribs, spiral chords, and growth striations. Some specimens have faint undulating ribs. However, the majority of adult shells do not have this character. Ribs, when present, are low and retrocurved. Thin spiral chords exist below the periphery of each whorl. Growth striations are apparent on all whorls. There is a faint hint of a decussate sculpture on the apical whorls. The aperture is elliptical in shape. The aperture is slightly concave in lateral profile. Because the figured specimen is slightly fractured, the longitudinal growth striations best indicate the direction of the curvature. In frontal view, the columella is moderately convex to straight with a thickening near its base. In the sub-adults, the aperture is ovate in shape. The base of the aperture extends as a tongue-like projection.

JUVENILE WHORLS.--The embryonic whorls are eroded from most specimens. The first post-embryonic whorl has a strong carina or keel located below the periphery Two carinae appear on the third whorl The first three apical whorls have a pitted appearance This condition is apparent up to the sixth whorl Carinae on the later whorls become spiral chords. Ribs may appear on the fifth whorl. Decussate sculpture becomes apparent on the third whorl

MATERIAL EXAMINED.--The material examined is listed in Appendix A.

DISTRIBUTION.--The species is found in the Escambia River system drainage north of the Alabama State Line including Big Escambia Creek, and the Sepulga River and the Conecuh River Populations that historically inhabited the Escambia River in Florida have been extirpated (Clench and Turner 1956)

HABITAT.--Snails were found burrowing through sand and silt and attached to aquatic plants limestone substrata river debris rocks and bridge pilings The tributaries vary in size from 3 to 50 meters in width a moderately fast current. The water was clear or stained light brown

Elimia species "B" new species

UNIQUE FEATURES.--The *lateral profile of the spire is slightly concave* The carina *begins on the second post-embryonic whorl below the periphery of whorl* The *shoulder of each whorl slopes at about 20 degrees (similar to* E. mutabilis*)* The *columella varies from being slightly twisted to straight*

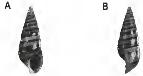

FIGURE 26. Adult shell of *Elimia* species "A", UF 241074, 26.5mm. A. Frontal view of the shell. B. Lateral view of the shell.

ADULT SHELL (Figures 28A-B).--The color of the periostracum ranges from golden brown to olive green. Some populations have dark to reddish brown bands on the spire and body whorl. The shape of the shell is elongate-conical. The apex of the shell is usually eroded leaving 3-7 whorls. The length of adult shells ranges from 8.2-23.2 mm. The spire is slightly concave in profile. The suture is well-developed between each of the whorls. The shoulder of each whorl slopes downward at about 20 degrees. Macrosculpture consists of carinae, spiral chords, ribs, and growth striations. The carina surround the whorl close to the suture. The carina of the upper whorls increases in size as a spiral chord in older whorls. Some specimens have slightly noticeable ribs on the upper whorls. The ribs, when present, are slightly retrocurved and much more pronounced than the ribs of species "A". The aperture is elliptical in shape. In lateral profile, the aperture is curved. The columella varies from being slightly twisted to straight. The columella thickens near its base. In juveniles, the aperture is ovate in shape.

JUVENILE WHORLS.--A carina begins on the second post-embryonic whorl below the periphery of whorl. This carina becomes more pronounced at the third whorl. The first post-embryonic whorl has a glossy, but pitted appearance. Decussate sculpture appears on the second whorl. Two carinae appear on the fourth whorl.

MATERIAL EXAMINED.--The material examined is listed in Appendix A.

DISTRIBUTION.--This species is located in the upper Choctawhatchee River and its tributaries. This species is also found in Murder Creek, a tributary of the Yellow River

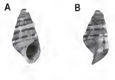

FIGURE 27 Adult shell of *Elimia* species "B", UF 222588 16.3 mm. A. Frontal view of the shell. B. Lateral profile view of the shell

HABITAT.--Snails were found burrowing through the sand and silt, and also attached to river debris, limestone substrata, and bridge pilings. The water clarity was clear or stained light brown. The tributaries were 10-60 meters in width in a moderately fast current.

Overview of Altamaha River Funa

The results of this study indicate that there are three morphologically distinct species in the Altamaha River system--*Elimia mutabilis*, *E. timida*, and an undescribed species. However, Goodrich (1942) reported *E. mutabilis* from streams in western Georgia and southern Alabama. Re-examination of the specimens identified by Goodrich as *E. mutabilis* from the Escambia and the Choctawhatchee River systems represent the two new species described above. These specimens were identified as *E. "curvicostata"* by Clench and Turner (1956) and by Chambers (1980).

Elimia (=*Goniobasis*) *timida* was described as a subspecies of *E. mutabilis* by Goodrich (1942). However, the results of this study show that *E. timida* is morphologically distinct and genetically unrelated to *E. mutabilis*, but it is closely related to *E. densicostata* of the Apalachicola River drainage system (Table 20).

The type locality of *E. timida* is problematic. The published locality was found to be questionable. Extensive field work within the area failed to the locate the stream cited in the description (Goodrich, 1942). The type specimen label revealed that the locality, handwritten by Clench, was "2.0 miles southeast of Hawkinsville". Goodrich (1942) stated "2.0 northwest of Hawkinsville". However, visits to both locality were futile in locating *E. timida*.

Synopses of the Altamaha River Species

Elimia mutabilis (Lea, 1862)

UNIQUE FEATURES.--*Undulating appearance by the cadnae crossing the ribs. Post-embryonic whorls have a straight lateral profile. The shoulder of each whorl slopes at about 30 degrees below the suture.*

ADULT SHELL (Figure 19).--The color of the periostracum varies from golden brown and olive green. Only one individual was found to have dark brown bands that encircled the upper whorls of the spire. The apex of the shell is often eroded, leaving 3-5 whorls. The length of the shell ranges from 15.9 to 22.8 mm. The shell is elongate-conical in shape. The spire is moderately convex in profile. The suture is well-defined between each of the whorls. The shoulder of the whorls slope at about 30 degrees below the suture. The macrosculpture consists of carinae, spiral chords, vertical ribs, and longitudinal growth striations. The penultimate whorl has 8 to 13 ribs. Some individuals do not have ribs. The lower whorls of the spire have 1-3 spiral chords that are located at, above, or below the periphery of the whorl. The body whorl may have 1-7 spiral chords that are located at, above, or below the periphery of the whorl. The shell microsculpture is very noticeably decussate. The aperture is elliptical in shape. In lateral view, the aperture is slightly curved. The columella is straight to curved in frontal view.

JUVENILE WHORLS.–The early whorls are straight in lateral profile. The carina begin at the first post-embryonic whorl halfway from the apex. The carina is located on the lower part of the each whorl just above the suture An indication of ribs appear about the third or fourth whorl As the carina cross over the ribs, it develops an undulating appearance Decussate sculpture becomes noticeably on the third whorl

MATERIAL EXAMINED.–Material examined is listed in Appendix A.

DISTRIBUTION.–This species was found at Snapping Shoals at South River, a tributary of the Ocmulgee River of the Altamaha River drainage system Further surveys of the lower Atlantic Coastal rivers are needed to determine the distribution of this species It is apparent that more than one species is involved Populations identified as *mutabilis* occur in the upper tributaries of the Altamaha River and the Ogeechee River

HABITAT.–This species was found attached to granite shoals in fast moving, clear water Snapping Shoals is about 100 meters in width, and spans a distance of about 400 meters

Elimia timida (Goodrich, 1942)

UNIQUE FEATURES.–*All adult shells are banded with the first band being yellow and the second band being reddish-brown (similar to* Elimia species "A") *Spiral chords undulate over the ribs appearing as a dashed line across the surface The ribs originate below the suture and end before the next suture*

ADULT SHELL (Figure 20) --The color of the periostracum ranges from olive green or golden brown. All specimens have two distinct bands that appear below the suture. The first band is yellow and the second band is a reddish-brown. The apex of the shell is usually eroded, leaving 4-10 whorls remaining. The length of the shell ranges from 8.5 to 11.9 mm. The shell is elongate-conical in shape. The spire is convex in lateral profile. The suture is well-defined between each of the whorls. There is no indication of a shoulder. The shell macrosculpture consists of carinae, spiral chords, vertical ribs and longitudinal growth striations. Spiral chords appear to undulate as they cross over the ribs appearing as a dashed line across the surface. The penultimate whorl of the spire may have a single spiral chord located above the periphery. The body whorl may have one or two spiral chords located above or below the periphery. The penultimate whorl has 11 to 22 vertical ribs. The space between the ribs is one quarter the length of the rib. The ribs are retrocurved and noticeable. The ribs originate below the suture and end before the next suture. Some individuals lack ribs on the penultimate whorl. The shell microsculpture consists of decussate striations. The aperture is ovate in shape. The aperture has a curved lip in lateral profile. The columella is slightly twisted in frontal view.

JUVENILE WHORLS --A carina develops halfway from the apex. The carina is located near the periphery of the whorl. Ribs begin on the third post-embryonic whorl. Carinae become spiral cords on the third post-embryonic whorl.

DISTRIBUTION.--This species was found in tributaries of the Ocmulgee River of the Altamaha River drainage system in Pulaski County, Georgia. Further surveys of the lower Atlantic Coastal rivers are needed to determine the complete distribution of this species.

MATERIAL EXAMINED.--Material examined is listed in Appendix A.

HABITAT.--Snails were found crawling through the sand or attached to limestone substrate and aquatic plants. Snails were found in clear spring runs in a moderately fast current. The streams were from 1 to 3 meters in width.

Elimia species "C" new species

UNIQUE FEATURES.--*The aperture is ovate-elliptical in shape and is straight in lateral profile. The columella fold is slightly twisted and thickened near its base. The spire is straight sided in juveniles and convex in adults.*

ADULT SHELL (Figures 28A, B).--The color of the periostracum ranges from olive green to dark brown. Some populations have dark brown bands. The apex of the shell is usually eroded, leaving 3-7 whorls remaining. The length of the shell ranges from 6.6 to 21.3 mm. The shell is elongate-conical in shape. In the earlier whorls of sub-adults the spire is straight in lateral profile. However the profile becomes convex in the adults. The suture is well-defined between each of the whorls. The shoulder of each whorl slopes at about 20 degrees below the suture. *The* shell macrosculpture consists of spiral chords, vertical ribs, and longitudinal growth striations. The lower whorls of the spire and the body whorl may have one to numerous spiral chords The shell microsculpture consists of a faint decussate striations The aperture is ovate-elliptical in shape and is straight in lateral profile The columella is slightly twisted and thickened near the base is convex in frontal view

JUVENILE WHORLS –The carina begin at the first whorl halfway from the apex, similar to Elimia mutabilis The carina is located on the lower part of the each whorl just above the suture Ribs appear about the fourth or fifth whorl Decussate sculpture becomes noticeable on the third embryonic whorl

MATERIAL EXAMINED –Material examined is located in Appendix A

DISTRIBUTION –This species was found in Rocky Creek a tributary of the Oconee River of the Altamaha River drainage system. Further surveys of the lower Atlantic Coastal rivers are needed to determine the complete distribution of this species.

HABITAT –Snails were found attached to rocks, woody debris and bridge pilings The stream bed consisted of sand silt, gravel and cobbles The streams ranged from 6 to 20 meters in width

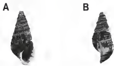

FIGURE 28. Adult shell of *Elimia* species "C", UF 41451 18.8 mm A. Frontal view of the shell. B. Lateral profile view of the shell

CHAPTER 5
DISCUSSION

According to Lydeard and Mayden (1995) Alabama and the adjoining states contain the highest diversity of freshwater fauna in North America Forty-three percent of the gill-breathing snails of North America reside within this region (Lydeard and Mayden 1995) Because the molluscan fauna is still in great need of taxonomic revision and resolution many species of snails and mussels are lumped under a single name (Thompson 1984). It is not uncommon to find new species that have been overlooked or misidentified This is discussed further in the section describing the use of shell morphology and mtDNA in pleurocerid taxonomic studies

This section also addresses several major topics that are relevant to the biodiversity biogeography and evolution of the "smooth" *Elimia* and other freshwater groups within the southeast. Other topics relevant to this discussion include the regional physiography and drainage evolution These subjects are relevant in understanding the dynamics of the origin and dispersal of freshwater groups in the region The final topic addressed in this chapter is conservation This section discusses biodiversity loss within the region the reasons for this decline potential future threats to its future and possible solutions

Regional Physiography

The present-day physiography of the region was molded from remnants of past geological formations (Mettee et al 1996) These remnants provide insights to interpreting the present-day faunal distribution patterns within the region (Swift et al. 1986) Also evolutionary and phylogenetic relationships of the region's fauna can be inferred from these distributional patterns (Swift et al 1986)

The river basins investigated in this study lie within the major physiographic provinces of the lower Piedmont, the Atlantic Coastal Plain and the Gulf Coastal Plain Many of the headwaters of these rivers originated above the Fall Line or on the lower Piedmont (Thompson 1939 Murray 1961 Hobbs 1981) These rivers then exit into the ocean via the Gulf of Mexico or Atlantic Coastal Plain

The Piedmont is a layer of hard sedimentary rock that extends from the base of the mountains to the alluvial sediments of the coastal plain The Piedmont stretches along the entire eastern coastline The area of the Piedmont Province within the study region rests between the Blue Ridge Valley of the Appalachians and the Fall Line Hills (Thompson 1939, Murray 1961, Hobbs 1981) The Piedmont is considered the non-mountainous part of the Older Appalachians (Fenneman 1938) This Province is composed of pre-Cretaceous rock, some of which is dated to be Triassic in origin (Hack 1969 Isphording and Fitzpatrick, 1992) The headwaters of the rivers originating on the Piedmont are composed of crystalline rock (Fenneman 1938) This rock type had restricted the northern migration of any of the southern Atlantic Coastal rivers from extending into the Blue Ridge Valley (Fenneman 1938)

The Fall Line is a geological boundary that separates the Piedmont from the coastal floodplains It also divides Alabama and Georgia into northern and southern sections (Thompson 1939 Murray 1961 Hobbs 1981) This geological boundary is composed of Cretaceous limestone and granite rocks of the Piedmont that occur in a restricted zone of 5 to 10 miles in width (Thompson 1939, Fenneman 1938). The term "Fall Line" is named for the occurrence of the many falls or rapids that are found within this zone (Fenneman 1938).

The Physiography of Georgia Rivers

In Georgia, the rivers originating above the Fall Line pass over the areas known as the Vidalia and Tifton Uplands and the Doughtery Plain (Hobbs 1981, Hodler and Schretter 1986). These areas contain very little level land. The rivers in this region are typically narrow and flow through small valleys. These rivers give rise to many shoals and rapids. The shoals are composed of granite, schist and gneiss which are Precambrian in origin (Murray 1961, Hobbs 1981). Also, some areas contain metamorphized intrusions of Paleozoic sediments that intersperse the landscape (Murray 1961, Hobbs 1981).

As the rivers flow southward over the Fall Line Hills, they cross unconsolidated deposits of recent origin (Hobbs 1981). These deposits are mixed with sand, limestone, and marl (Hobbs 1981). The rivers continue to flow over the Coastal Plains where they encounter Cretaceous sediments (Murray 1961, Hobbs 1981). The stream substrata is comprised of Cretaceous sediments consisting of sand, clay, and gravel (Murray 1961, Hobbs 1981).

The Physiography of Alabama Rivers

The Alabama rivers flow over the major land provinces called the Piedmont and the Gulf Coastal Plain. The Coosa and Apalachicola Rivers originate above the Fall Line Hills on or above the Piedmont Province. Rivers originating above the Fall Line have streambeds composed of sedimentary rocks consisting of sand, gravel, porous limestone, chalk, marl, and clay (Mettee et al. 1996). The Blackwater, Conecuh, Choctawhatchee, Pea, and Yellow Rivers originate below the Fall Line.

The East Gulf Coastal Plain occupies 50 percent of the area in southern Alabama (Mettee et al. 1996). Streambeds below the Fall Line consist mainly of mud or sand (Mettee et al. 1996). These lower streams travel through gentle rolling hills with little topographic relief (Mettee et al. 1996).

The headwaters of the Escambia and Choctawhatchee Rivers originate in an area occupying the far southeast end of the state called the Chunnenuggee Hills (Mettee et al. 1996). The Chunnenuggee Hills are located directly below the Fall Line (Mettee et al. 1996). These areas are composed of beds of clay, sandstone, siltstone and chalk.

The subsection of the Coastal Plain called the Dougherty Plain extends from Georgia into the southeastern corner of Alabama (Mettee et al. 1996). The Doughtery Plain lies adjacent to the eastern edge of the Lime Hills and the western edge of the Southern Red Hills. This region is composed of limestone, sand and clay (Mettee et al. 1996). The underlying limestone contains many shallow flat-bottom depressions that dot the landscape. These flat-bottom depressions are caused by the dissolution of limestone which divert surface water to underground channels (Mettee et al. 1996). This diversion of surface water eliminates any small headwater streams from the Doughtery Plain.

The Yellow and Blackwater Rivers originate in the lower part of Alabama's Doughtery Plain. These rivers transverse over the region called the Southern Pine Hills. This area contains high concentrations of dissolved organic matter or tannins from the natural flora creating blackwater creeks.

The Physiography of Florida Rivers

The Gulf Coastal rivers and streams of west Florida originate in southern Alabama or western Georgia. Rivers and streams flowing through west Florida are categorized on the basis of their overall streambed composition. This area contains predominately sand-bottom or calcareous streams (Beck 1965, Nordlie 1977). Sand-bottom streams are the most abundant stream type found in the Florida Panhandle (Beck 1969; Nordlie 1977). These streams flow over the Marianna and Western Highlands of the Florida Panhandle. These areas have rolling hills that are characteristic of this region.

The Blackwater and Yellow Rivers are the predominate sand-bottom streams of west Florida. Pleurocerid snails have not been recovered from the Blackwater River, and have only been found from the Murder Creek tributary of the Yellow River. The absence of pleurocerid snails may be due to the high (acidic) pH of the water.

The calcareous streams of western Florida are the Chipola River and Holmes Creek, which originate primarily at springs (Nordlie 1977). There are many springs that discharge into the Chipola River and Holmes Creek. Many areas within these rivers have sections containing sand-bottom substrata lined with exposed limestone and shoals.

The calcareous streams of Florida contain the greatest abundance and diversity of *Elimia* species within the entire study region (Nordlie 1977). For example, the Chipola River and Holmes Creek yield five sympatric *Elimia* species that are not found elsewhere in the study area.

The larger rivers surveyed in Florida are the Apalachicola, Choctawhatchee and Escambia. These rivers originate in the upland hills of Alabama and Georgia (Beck 1965, Hobbs 1981, Mettee et al. 1992). The Apalachicola is the only Florida river to originate between the Piedmont and southern Appalachian Mountains of northwest Georgia and northeast Alabama (Swift et al 1986) These rivers exit into the ocean discharging a large volume of water Because of this large discharge volume enormous amounts of clay and silt are carried from their headwater tributaries making these rivers extremely turbid (Beck 1965)

Unraveling Taxonomic Problems

Using Shell Morphology and Mitochondrial DNA

The use of shell morphology in the identification of pleurocerid species has been problematic. Because of the high level of convergence among shell characters in this group many taxonomic identifications are difficult or ambiguous(Chambers 1978 1978 1980 1981 1990 Dillon and Davis 1980 Dillon 1984 Thompson 1984)

This study was able to use quantitative and qualitative shell characters to differentiate and distinguish among the adult *Elimia* species within the region The quantitative characters most useful in differentiating the taxa were aperture shape and overall shell length The qualitative features such as the spire s lateral profile columella shape and rib shape were also useful in distinguishing among the species Furthermore the presence of sculpture patterns such as spiral cords and vertical ribs was another qualitative feature useful in species identifications

Many pleurocerid taxonomic descriptions were written prior to the 1900's when naturalists may have underappreciated phenotypic variation One manifestation of this problem was the classification of subadults and adults as seperate taxa Ultimately this compounded the problems associated with the taxonomy of this group (Reeve 1859-1861 Tryon 1863-65 1873 Lea 1862b 1862c 1862d 1863 1864 1867)

The sequence comparisons of cytochrome oxidase gene subunit 1 proved informative in differentiating the *Elimia* species. The nucleotide divergence among the morphologically distinct species ranged from 9-20%. The nucleotide divergence of *E. densicostata* populations from the Chipola and Apalachicola Rivers was 3%. Nucleotide divergence among the pleurocerid genera *Elimia* and *Pachychilus* was about 30%.

Cytochrome oxidase sequences from the mtDNA were also useful in discerning phylogenetic relationships between the river basins. The regional *Elimia* consisted of two major assemblages--a western and an eastern assemblage. The western assemblage includes *Elimia* species "A" and "B" of the upper Choctawhatchee, Yellow and Escambia Rivers. The western assemblage is more closely related to *E. olivula* from the Alabama River system then it is to the species of the eastern assemblage.

The eastern assemblage of species includes *Elimia densicostata*, *E. dickinsoni* and *E. timida*. The distribution of this assemblage includes the Apalachicola and Altamaha River systems. Also, the distribution of these snails extends into the tributaries of the lower Choctawhatchee (Wrights and Holmes Creeks). The other Altamaha snail, *E. mutabilis*, was unrelated from either assemblage.

Biodiversity and Biogeography of the Southeastern Rivers

Elimia Biodiversity and Faunal Distribution

This investigation was able to document nine "smooth" *Elimia* species within the defined study area (Table 21). *Elimia densicostata*, *E. dickinsoni*, *E. ucheensis*, *E. viennaensis* and two undescribed species occur in the Gulf Coastal river drainages of

Florida, Alabama, and Georgia. *Elimia mutabilis*, *E. timida*, and another undescribed species are confined to the river drainages of the Atlantic Coastal Plain in Georgia.

Each of the Gulf Coastal species is restricted to single river drainage systems except for *E. densicostata* and *E. dickinsoni*. *Elimia densicostata* inhabits the Chipola and Flint Rivers of the Apalachicola River drainage system. This species is also found in the lower tributaries of the Choctawhatchee River system of Florida. A closely related species to *E. denicostata* called *E. dickinsoni* has a similar distribution. *Elimia dickinsoni* and *E. densicostata* occur sympatrically at some localities.

The other two species confined to separate tributaries of the Apalachicola River drainage are *E. viennaensis* and *E. ucheensis*. *Elimia viennaensis* is restricted to the Flint River of the Apalachicola River drainage system. This taxon occurs sympatrically with *E. densicostata* in the sand-bottom tributaries of the Flint River. However, these two species are genetically unrelated and morphologically distinct (Mihalcik in press). *Elimia ucheensis*, the other smooth form confined to the Apalachicola River drainage has only been recorded from the Uchee Creek system of the Chattahoochee River. It is also morphologically distinguishable from the other Apalachicola *Elimia*. The genetics of this species still remains to be examined. The two undescribed taxa, *Elimia* species "A" and "B", were found in separate drainages in the Gulf Coastal Rivers of Florida and Alabama. *Elimia* species "A" inhabits the Escambia River system and its tributaries. *Elimia* species "B" is found in the upper Choctawhatchee River and its tributaries. Both of these taxa are morphological distinct but should be considered sister taxa. These species were originally masked under the name *Elimia curvacostata*.

The smooth *Elimia* forms within the Altamaha River system revealed three distinct taxa–*E. mutabilis*, *E. timida*, and *Elimia* species "C". Because of the limited

TABLE 21 Distribution of selected freshwater taxa within the southeastern river systems. The taxa are indicated in the far left column under the category of freshwater fishes, turtles, snails, mussels, crayfishes, caddisflies, and mayflies. The river systems are identified in the upper row: MISS – Mississippi, TOM = Tombigbee, ALB = Alabama, COO = Coosa, ESC – Escambia, BLW = Blackwater, YEW = Yellow, CHO – Choctawhatchee, APA = Apalachicola, CHA = Chattahoochee, FLT = Flint, ALT – Altamaha, OGE = Ogeechee, SAV = Savannah, EDI = Edisto, SAN = - Santee. The column CITE refers to the references listed at the end of the table. The following symbols are used: X = occurs in system, EN – endemic, EX = extinct, I = introduced, ? = no positive record, *= distribution recorded by current study

	MIS	TOM	ALB	CO	ESC	BLW	YEW	CHO	APA	CHA	FLT	ALT	OGE	SAV	EDI	SAN	NOTES
Freshwater Fishes																	
Ameiurus strapiculus					X	X	X	X		X							F,P
Ammocrypta asprella	X	X	X	X	X												I,y,F,P
Ammocrypta bifascia					X	X	X	X	I								y,F P
Campostoma oligolepis	X	X	X	X	X												D,F,P
Campostoma pauciradii										X	X	X					F,P
Carpiodes velifer	X			?	X			X									E,F,P
Cyprinella callitaenia									EN	EN	EN						k,I,E F P
Cyprinella callisema												X	X				k,E F P
Cyprinella gibbsi				X						X							I,I E F P
Cyprinella xaenura												EN					j E F P
Cyprinella venusta	X	X	X	X	X	X	X	X	X	X	X						k F P
Erimyzon tenuis		X	X	?	X	X	X	X									x E F,P
Etheostoma chlorosomum		X	X	X													k,x,F P,Y
Etheostoma davisoni					X	X	X	X									r,C F P
Etheostoma edwini					X	X	X	X	X								x,C F N P
Etheostoma hopkinsi												X	X	X			x,C G F P
Etheostoma inscriptum												X	X	X			C F P
Etheostoma parvipinne		X		X	X			X	X	X	X	X					x,C F P
Etheostoma proeliare		X	X		X												x C,F P
Etheostoma serrifer		X	X	X						X							F P q
Etheostoma stigmaeum		X	X	X	X	X	X										r F P
Etheostoma swaini		X		X	X	X	X	X	X	X	X						r F M P

TABLE 21 --Continued

	MIS	TOM	ALB	CO	ESC	BLW	YEW	CHO	APA	CHA	FLT	ALT	OGE	SAV	EDI	SAN	NOTES
Freshwater Fishes																	
Micropterus new species									EN	EN	EN						*j*
Moxostoma species									EN	EN	EN						*j*
Moxostoma lachneri									EN	EN	EN						*q s,E,F,P*
Moxostoma robustum												X			X	X	*q s,F C,P*
Moxostoma rupiscartes										X		X	X	X	X	X	*q,s,E F G P*
Notropis baileyi		X	X	X	I					X							*K,E F G P*
Notropis cummingsae									X	X		X	X	X			*k,E,F G P*
Notropis euryzonus										EN							*k,C E F P*
Notropis hypselopterus		X	X	X	X	X	X	X	X	X	X	X	X	X			*l,C E F P*
Notropis hypsilepis										X	X			X			*o,C E F P*
Notropis longirostris	X			X	X	X	X	X	X	X	X						*C F,P*
Notropis lutipinnis										X		X	X	X	X	X	*l,q C E,F,P*
Notropis maculatus		X	X					X		X					X	X	*q C E F P*
Notropis petersoni					X	X	X	X	X	X	X				X	X	*o,q C,E,F,P*
Notropis signipinnis					X	X	X	X	X								*l C E F P*
Notropis texanus	X	X	X	X	X	X	X	X	X	X	X						*l C E F O P*
Notropis welaka		X			X	X	X	X	X								*k,C E F P*
Notropis zonistius		X	I						X	X	X	I		X			*C F P*
Noturus leptacanthus		X	X	X	X	X	X	X	X	X	X		X	X	X	X	*j C F P*
Percina species					X	X	X	X									*q,j Q*
Percina vigil		X	X	X	X												*F*
Pimephales notatus		X	X	X	X												*F,P*
Freshwater Turtles																	
Graptemys barbouri					X	X	X	X	X	X	X						*h,g,l,w y z E I*
Graptemys ernsti					X		X										*g h w y z*
Graptemys n. nigrinoda				EN													*g h w y z*
Graptemys pulchra		X	X	X	X		X	X	X								*g,h,k,w y z,J*
Macroclemys temminckii	X	X	X	X	X	X	X	X	X	X	X	X					*g h,w H*
Sternotherus minor	X	X	X	X	X	X	X	X	X	X	X	X	X				*g h w y*

TABLE 21 --Continued

	MIS	TOM	ALB	CO	ESC	BLW	YEW	CHO	APA	CHA	FLT	ALT	OGE	SAV	EDI	SAN	NOTES
Freshwater Snails																	
**Elimia species "A"*					EN												
**Elimia species "B"*								EN									
**Elimia species "C"*												X	?				
Elimia albanyensis									EN		EN						f V
Elimia athearni								X	X								f V
Elimia clenchi								EN									f V
**Elimia densicostata*									X		X						c,f
**Elimia dickinsoni*									X		X						c,V
Elimia floridensis								X	X								T V
**Elimia mutabilis*												X	?				m,V
**Elimia timida*												X	?				m,V
**Elimia ucheensis*										X							c,V
**Elimia viennaensis*											EN						f V
Campeloma geniculum					X			X	X								T V
Campeloma limum					X			X				X	X	X	X	X	T,V
Lioplax choctawhatchensis								EN									c T V
Lioplax pilsbryi									EN								T V
Lyogyrus latus											X	X	X				U V
Marstonia halcyon													EN				S V
Notogillia sathon												EN					R,V
Spilochlamys turgida												EN					R V
Viviparus georgianus								X	X			X					v T V
Viviparus goodrichi								X	X	X							v w V
Freshwater Mussels																	
Alasmidonta arcula												EN					d V
Alasmidonta triangulata									X				X	X			f V
Amblema neislerii									EN		EN						f V
Anodonta heardi									EN								n,V
Elliptio chipolaensis									EN								f V
Elliptio dariensis												X					f V

TABLE 21 —Continued

	MIS	TOM	ALB	CO	ESC	BLW	YEW	CHO	APA	CHA	FLT	ALT	ORE	SAV	EDI	SAN	NOTES
Freshwater Mussels																	
Elliptio shepardiana												EN					f,V
Elliptio spinosa												EN					f,V
Fusconaia escambia					X		X										f,V
Fusconaia succissa					X		X	X									f,V
Lampsilis australis					X		X	X									f,V
Lampsilis binominata										EX	EX						V,A
Lampsilis dolabraeformis												X	X				f,V
Lampsilis haddletoni								EN									f,V
Lampsilis radiata splendida												X	X	X			f,V
Lampsilis subangulata								X	X								f,V
Obovaria rotulata					EN												f,V
Pleurobema strodeanum					X		X	X									f,V
Ptychobranchus jonesi								EN									f,V
Pyganodon gibbosa												EN					f,V
Quincuncina burkei								X									f,V
Villosa choctawensis								EN									u,V
Utterbackia peggyae								X	X		X						f,V
Freshwater Crayfishes																	
Cambarus acanthura										X		X					p,Z
Cambarus acutus					EN												o,Z
Cambarus bartonii										X		X		X			p,Z
Cambarus cryptodytes											EN						p,Z
Cambarus diogenes										X	X	X					p,Z
Cambarus howardi										EN							p,Z
Cambarus harti										EN	EN						p,Z
Cambarus latimanus										X	X	X	X	X			p,Z
Cambarus striatus										X	X	X		X			p,Z
Cambarus truncatus												EN					p,Z
Distocambarus devexus										X	X	X	X				p,Z
Fallicambarus hedgpethi										EN	EN						p,Z
Faxonella clypeata										X	X	X	X				p,Z

TABLE 21 —Continued

	MIS	TOM	ALB	CO	ESC	BLW	YEW	CHO	APA	CHA	FLT	ALT	OGE	SAV	EDI	SAN	NOTES
Freshwater Crayfishes																	
Procambarus lavittatus					EN												o,Z
Procambarus barbatus												X	X	X			p,Z
Procambarus enoplosternum												X	X	X			p,Z
Procambarus gibbus											EN						p,Z
Procambarus howellae											X	X					p,Z
Procambarus lunzi												X	X				p,Z
Procambarus pubescens												X	X	X			p Z
Procambarus pygmaeus												X	X	X			p Z
Procambarus raneyi												EN					p,Z
Procambarus seminolae											X	X					p,Z
Procambarus shermani					EN												e,Z
Procambarus spiculifer										X	X	X		X			p,Z
Procambarus troglodytes												X	X	X			p,Z
Procambarus truculentus												X	X				p,Z
Caddisflies																	
Agarodes Agarodes ziczac						EN											A D
Cheumatopsyche petersi						EN											A,D
Mayflies																	
Dolania americana						X	X							X			b,w P
Homoeoneuria dolani						X	X							X			b,w P
Pseudiron meridionalis						X	X			EX							b,w P

TABLE 21.--Continued.

Notes
a Berner L 1977 p. 30
b Berner and Pescador 1988. p. 22.
c Burch J 1989 pp 90 131
d Burch J 1975 pp 32 56 64 67 68 73, 83 103 105 118, 120
e Buth D G and R W Murphy p 401
f Clench W B and R. Turner 1956 pp 132, 136 139 141, 152 160 175 181 201
g Collins J T 1987 pp 1-41
h Ernst C H and R W Barbour 1972 pp 32 37 46 114 117 123 126 258 265 269
i Gibbs 1957 p 189
j Gilbert C. 1978a-c pp. 13-14, 19-21 23-28 32-33, 47-50
k Gilbert C 1980a-j pp 245 247 259 263 267 268 323 326 634
l Gilbert C R and G H Burgess 1980 pp 294 306 321 437
m Goodrich C. 1942 p 5
n Gordon M E and W R Hoeh 1995. p. 270
o Hobbs H H 1942 pp 20-21
p Hobbs H H 1981 pp 36 74
q Hocutt et al 1980 p 840
r Howell W M 1980a b pp 640 697
s Jenkins R E 1980a-c. pp 432 433
t Iverson J B 1977 p 503
u Johnson R I 1969 p 300
v Katoh M and D W Foltz. 1994 p 86
w King F W and R. L. Burke 1989 pp 28 53-56 87 106 107
x Kuehne R. A. and R W Barbour 1983 pp 60 61 78 109 123, 137 141 145 163
y Lamb et al 1994 p 545
z McKnown R. R. 1972. p 23.
A Morse J 1982. pp 52-54
B Page L M 1983 pp 52, 55 65 109 116 140 157
C Page L M and B M Burr 1991 pp 118 119 126-127 140-141 147-148 150 159 161 166 180 185 187 186 195
D Peters W 1982 pp 28-31
E Pritchard P C H 1976 pp 53-54 69-71
F Robins et al. 1991 pp 1-83
G Rohde, F C 1980a,b pp 654 690
H Roman J 1967 p 22
I Sanderson R. A. 1976 pp 49-50

J Shealy, R. M. 1976a, pp. 50-51
K Shealy, R. M. 1976b, p. 58
L Sneelson, F. F. 1985, pp. 8-10
M Starnes, W. C. 1980a-b, pp. 656, 699
N Stauffer Jr., J. and C. H. Hocutt. 1980a, b, p. 843
O Swift, C. C. 1980a-c, pp. 278, 294, 318
P Swift et al. 1985, pp. 153, 165, 166, 168, 256-262, 264.
Q Thompson, B. A. and R. C. Cashner. 1980, p. 732
R Thompson, F. G. 1969, pp. 254, 255, 259
S Thompson, F. G. 1977, p. 153
T Thompson, F. G. 1984, pp. 12, 18, 24, 28, 30
U Thompson, F. G. and B. Hershler. 1991, p. 168
V Turgeon et al. 1988, pp. 1-277
W Walker et al. 1995, p. 367
X Walker et al. 1997, p. 18
Y Wall Jr., B. R. and C. R. Gilbert. 1980, p. 400
Z Williams et al. 1989, pp. 1-77
A' Williams et al. 1992b, p. 12
B' Yerger, R. W. 1978, pp. 26-27

field sampling within the Atlantic Coastal drainages, I cannot rule out the possibility that these taxa may occur outside the Altamaha River basin Nonetheless, these species do not occur in the Gulf Coastal rivers *Elimia mutabilis* was found in the rocky shoals at the headwaters of the Oconee River However the undescribed taxon, *Elimia* species "C", inhabits the rocky shoals of the lower tributaries of the Oconee River The remaining species *E timida* inhabits small headwater streams of the Ocmulgee River

Biodiversity of other Southeastern Freshwater Groups

The biodiversity of the southeastern freshwater fauna is one of the richest in temperate North America (Mayden and Lydeard 1994) Many studies have documented the freshwater diversity that exists in crayfish mussels snails mayflies caddisflies fish and turtles within the southeastern river drainages (Hobbs 1942 1981, Clench and Turner 1956 Gibbs 1957 Johnson 1970 Berner 1977 Thompson 1977 Burgess and Franz 1978 Peters 1982 Morse 1982 Swift et al 1986 1985 Gilbert 1987 Berner and Pescador 1988 Thompson and Hershler 1991 Katoh and Foltz 1994 Lydeard and Mayden 1995 Roman 1997) These taxa primarily inhabit the river environment and not the adjacent floodplain The majority of these groups are strictly aquatic except for the caddisflies and mayflies Only the larvae of these insects are aquatic Also the turtles of the genus *Graptemys Sternotherus* and *Apalone* are considered semi-aquatic in nature

A high number of endemic species exists within the southeastern rivers (Nordlie 1977 Swift et al 1986 Lydeard and Mayden 1995) Many species are endemic to a single river system a pattern which is similar to other fish faunas in eastern North American rivers (Hobbs 1942 1981 Thompson 1969 Johnson 1970, Gilbert 1978a-c Morse 1982 Peters 1982 Swift et al 1979 1986 Mayden 1988) The Apalachicola

River drainage contains the greatest number of species of freshwater fish and mollusks than any other adjacent Gulf Coastal drainage excluding the Mobile basin (Clench and Turner 1956 Swift et al 1986)

The greatest concentration of endemic species that exist within the study region is found in the Apalachicola River drainage system This drainage system offers the greatest faunal diversity of available stream habitats because of the heterogeneity of its substrata The endemic Apalachicola fauna consists of six vertebrate taxa of which five are freshwater fish and a single freshwater turtle (Gilbert 1978a c, Gilbert 1980c,d a Sanderson 1976) (Table 21) The endemic freshwater fish species are *Cyprinella callitaenia* *Micropterus sp.* (undescribed) *Moxostoma lachneri* *Moxostoma sp* (undescribed) and *Notropis euryzonus* The other vertebrate taxon is *Graptemys barbouri* (Sanderson 1976)

The number of endemic invertebrates far outnumber the endemic vertebrates in the Apalachicola River system Six crayfish species are endemic to the Apalachicola River and its tributaries. The six crayfish species are confined to the Piedmont Province of the Flint and Chattahoochee Rivers The crayfish species are *Cambarus cryptodytes* *C harti* *C. howardi* *Fallicambarus hedgpethi* *Procambarus acutissimus* and *P gibbus*

There are six mollusk species endemic to the Apalachicola River basin (Clench and Turner 1956, Burch 1970) (Table 21) The endemic snails are *Elimia albanyensis* *E vennaensis* and *Lioplax pilsbryi* *Elimia albanyensis* is distributed from the shoals immediately downstream of the Woodruff Dam on the Apalachicola northward to the tributaries of the Flint River (Thompson 1984) *Elimia vennaensis* is found exclusively in the Flint River tributary of the Apalachicola drainage The third species *Lioplax pilsbryi* is confined to the Chipola River of the Apalachicola River system (Thompson 1984)

The endemic mussels of the Apalachicola River drainage are *Amblema neislerii* *Elliptio chipolaensis* *Anodonta heardi* and *Lampsilis binominatus* (Burch 1970) The first three species are restricted to single tributaries within the Apalachicola River system However *Lampsilis binominatus* is currently reported to be extinct (Williams et al 1992a) The former distribution of this species included the Chattahoochee and Flint Rivers of the Apalachicola drainage

The lowest number of endemic species occur in the Blackwater, Choctawhatchee Escambia and Yellow Rivers of the Gulf Coastal Plain The Blackwater and Yellow Rivers are identified as sand-bottom streams that contain the fewest number of endemics, and the least diverse of habitats The only endemic invertebrates to these rivers exclusively are the caddisfly and mayfly species listed in Table 21 These insects are important to the region because they are ecologically dependent on cool sand-bottom streams for larval development

Within the Escambia and Choctawhatchee Rivers there are only a few vertebrate and invertebrate species endemic to individual river systems. The only vertebrate species endemic to the Escambia and Yellow Rivers is the freshwater turtle species, *Graptemys ernsti* (Sanderson 1976) The other endemic vertebrates are the freshwater fish *Ameiurus atrapiculus*, *Ammocrypta bifascia* *Etheostoma davisoni* *E. edwini* *Notropis signipinnis*, and an undescribed *Percina* species (Gilbert et al 1980 Swift et al 1985 Robins et al 1991)

The endemic freshwater invertebrates include three crayfish, ten mussel and four snails. The endemic crayfishes in the Escambia River basin are *Cambarus acutus*, *Procambarus bivittatus* and *P. shermani* (Table 21). There are other endemic crayfish within the Florida Panhandle but their distribution is not restricted to the river environment (Hobbs 1942).

A greater number of mollusk species are endemic in the Escambia, Choctawhatchee, and Yellow Rivers. These species include *Fusconaia escambia*, *F. succissa*, *Lampsilis australis*, *L. haddletoni*, *L. subangulata*, *Obovaria rotulata*, *Pleurobema strodeanum*, *Ptychobranchus jonesi*, *Quincuncina burkei* and *Villosa choctawensis*. Four of these species are confined to single river drainages while the remaining six species occur in several river systems (Table 21). The four snails endemic to this region are *Elimia clenchi*, *Elimia* species "A" and "B", and *Lioplax choctawhatchensis*. These species are confined to single river systems.

The southern Atlantic Coastal river drainages contain a much larger endemic freshwater vertebrate and invertebrate fauna (Clench and Turner 1956, Hobbs 1981, Swift et al. 1985). The endemic vertebrates include the freshwater fish species *Cyprinella callisema*, *C. xaenura*, *Etheostoma hopkinsi*, and *E. inscriptum*. These species are endemic to the Altamaha and Ogeechee Rivers except for *Cyprinella xaenura* which is endemic only to the Altamaha River system.

There are thirteen mollusk species endemic to the southern Atlantic Coastal drainages (Table 21). Four of these endemics are freshwater snails confined to the Altamaha River basin. These snail species are *Marstonia halcyon*, *Notogillia sathon*, *Spilochlamys turgida* and *Viviparus georgianus*. The endemic mussel species include

Alasmidonta arcula A triangulata Elliptio dariensis, E. hopetonensis, E shepardiana, E spinosa Lampsilis dolabraeformis, L. radiata splendida and *Pyganodon gibbosa*

The southern Atlantic Coastal rivers include a greater number of endemic freshwater crayfish species than the Gulf Coastal river fauna (Table 21) These species are confined to the Piedmont Province of the Altamaha, Ogeechee and Savannah River drainages The endemic crayfish include *Cambarus truncatus, Procambarus acutus, P advena, P barbatus, P enoplosternum P lunzi, P pubescens, P pygmaeus P raneyi* and *P troglodytes* (Hobbs 1981)

Biogeography of the other Southeastern Groups

The biogeography of the southeastern rivers have been studied in great detail for the freshwater fishes and freshwater turtles (Avise and Bermingham 1986; Swift et al. 1986) The study by Swift et al (1986) was based on species and subspecies distributions within the southeastern drainages This study showed that the species distributions within the Gulf and Atlantic Coastal drainages included distinct western and eastern assemblages The western assemblage included species from the Apalachicola River system westward to Louisiana (Swift et al 1986) The eastern assemblage included fish species in all the southern Atlantic Coast and the Florida peninsula drainages (Swift et al 1986)

Another major study used DNA to examine the distribution of freshwater fish population haplotypes within the southeastern drainages (Avise and Bermingham 1986) Avise and Bermingham (1986) chose several sunfish species and *Ava gamer* for their study Within each species, major phylogeographic breaks were noted between eastern and western populations The eastern haplotype populations were from populations of the Cooper River system of South Carolina to the Gulf Coastal Apalachicola River. The western populations were composed of the population from the Escambia River to the Mississippi River.

The biogeographic and phylogeographic studies pertaining to the freshwater turtles showed a similar but not identical scenario to the that of the freshwater fishes. The studies of *Sternotherus minor* indicated that the tributaries of the lower Choctawhatchee and Apalachicola Rivers were genetically similar to the populations in the Atlantic Coastal river systems (Walker et al. 1995). These findings are also reflected in the genetic results of the *Elimia* species in this study.

Endemic haplotypes of *Macroclemys temminki* were found in almost every the Gulf Coastal drainages. However, haplotypes were shared between the lower Choctawhatchee, Chipola, Apalachicola, and the Ochlockonee Rivers. Roman (1997) found that these populations shared an affinity with the Pensacola (lower Escambia) and Mobile (lower Alabama) Bay populations.

The southern Atlantic Coastal rivers of the Savannah, Ogeechee, and Altamaha share freshwater fish and invertebrate fauna. The freshwater fish species that inhabit these drainages are *Cyprinella callisema*, *Etheostoma hopkinsi*, and *E. inscriptum*. The invertebrate fauna consists of two species of freshwater mussels (*Lampsilis dolabraeformis*, *L. radiata splendida*) and ten freshwater crayfish species (*Procambarus acutus*, *P. advena*, *P. pygmaeus*, *P. truculentus*, *P. barbatus*, *P. enoplosternum*, *P. lunzi*, *P. pubescens*, *P. troglodytes*).

The southern Atlantic Coastal river systems of the Savannah, Ogeechee, and Altamaha within the study area share invertebrate fauna with the Apalachicola River system. This is evident by the distribution of the freshwater mussels, snails and crayfishes within the region (Table 21) This river faunal exchange is also reflected in this study by the genetic relationships among the Apalachicola and Altamaha *Elimia* species

Origin, Dispersal, and Evolution of the Region's Fauna

The results from this study and other previous works have demonstrated that the fauna of the southeastern rivers originated from four major sources the Alabama Mississippi Tennessee and the Santee River systems This is evident from the distribution of freshwater species within the region (Table 21) The number of species that colonize a river system are usually dependent on the distance from the source (Swift et al 1986) Also the species number is indicative of the suitable physical characteristics of the stream (Beck 1969) Both of these factors may explain the low number of species in the Gulf Coastal rivers of the Florida Panhandle excluding the Apalachicola River system (Swift et al. 1986)

From the Mississippi River system the influx of the western fauna can be demonstrated by freshwater fishes and turtles (Swift et al 1986 Roman 1997) Seven freshwater fish species have distributions that extend from the Mississippi to the Escambia River system (Table 21) These seven species include *Ammocrypta asprella Campostoma oligolepis Carpiodes velifer Cyprinella venusta Notropis longirostris*, and *N texanus*. The distribution of the freshwater turtle species that extend from the Mississippi to the Escambia River system include *Macroclemys temminckii Sternotherus minor S odoratus*, and *Apalone spinifera aspera*

A second influx of freshwater fish and turtle species originating in the Alabama River system moved eastward into the Florida Panhandle These freshwater fish species include *Erimyzon tenuis Etheostoma chlorosomum E parvipinne E proeliare*

E serrifer E stigmaeum E swaini Notropis hypselopterus, *N maculatus N welaka Percina vigil* and *Pimephales notatus* The influx of freshwater turtle species include *Graptemys pulchra* and *Apalone spinifera aspera*

The Tennessee River is the geographic center for many of the species in the southern Atlantic Coastal river systems and the Apalachicola River system (Gibbs 1957) Evidence for this is demonstrated by biogeographical and morphological analyses of freshwater fish and mollusk species (Gibbs 1957 Johnson 1971, Swift 1977, Thompson 1977, Swift et al 1986, Thompson and Hershler 1991) According to Swift (1977) many fish species within the Tennessee River drainage were funneled into the Atlantic Coastal rivers by headwater stream capture Gibbs (1957) postulated that the Tennessee cyprinid fish stocks colonized the Atlantic Coastal rivers via the Savannah River system These stocks later moved into the Apalachicola River system via the Altamaha River drainage (Gibbs 1957) An example of this southwestward movement is the distribution of the freshwater fish *Notropis hypsilepis* and *N zonistius* These fish are endemic to the Apalachicola but have conspecifics located in the upper part of the Savannah River drainage

The distribution of invertebrate groups indicate that the Tennessee River fauna did enter the Atlantic Coastal streams This is illustrated by the crayfish species *Cambarus latimanus* and *C striatus* Both of the crayfishes are found in the Tennessee, Coosa, Apalachicola Altamaha Ogeechee and Savannah River systems Also the hydrobiid snails of the genus *Marstonia* probably originated in the Tennessee River system (Thompson 1977) Based on studies of conspecifics associated with the Tennessee River and Atlantic coastal drainages Thompson (1977) concluded that these hydrobiid snails later spread from the Coosa River of Alabama to the Flint, Ocmulgee and Ogeechee Rivers of Georgia via the Savannah River system (Thompson 1977)

The Hiwassee River of North Carolina has been hypothesized to be another alternative route for a faunal exchange from the Tennessee basin to the rivers of the southern Atlantic coastal plain This fauna then entered into the Chattahoochee River headwater tributary to the Apalachicola River system (Hobbs 1981) Hobbs (1981) suggested that stocks certain crayfish species such as *Cambarus bartonii* may have entered the Chattahoochee River via the Hiwassee River But this interpretation was based merely on conjecture (Hobbs 1981) No evidence has surfaced to substantiate this hypothesis

There was another colonization of the Atlantic Coastal rivers from the Coosa-Etowah Rivers of the Alabama River system This event is demonstrated by five freshwater fish species that have entered the Apalachicola River system and the Chattahoochee River via the Etowah-Coosa connection (Table 21) These five species are *Cyprinella gibbsi*, *Etheostoma senifer* *Luxilus zonistius* *Notropis baileyi* and *N masculatus*

Another northeastern colonization of freshwater fishes moved into the southern Atlantic Coastal river systems from the Santee and Edisto Rivers of South Carolina (Swift et al 1986 Hobbs 1981) This fauna also moved into the Apalachicola River drainage from the Altamaha basin The seven freshwater fish species used this route are *Ameiurus brunneus*, *Hybopsis rubrifrons* *Hypentelium etowanum* *Moxostoma robustum* *M rupiscartes* *Notropis lutipinnis* and *N petersoni*

Several geographical and ecological barriers have restricted the region's freshwater fauna from migrating upstream and moving between the river basins These barriers include the Fall Line Hills, the Doughtery Plain, and the area of land between the Chattahoochee/Apalachicola and Flint Rivers (Hobbs 1942 Mettee et al 1996) Also, the river drainage systems being confined to non-overlapping floodplains have acted as isolating mechanisms (Swift et al 1986)

The ecological barriers restricting faunal exchange between drainages include the physical characteristics of the river such as water quality and available substrata. These factors must also be taken into consideration when addressing the absence of species in the rivers such as the Blackwater and Yellow of the Gulf Coast. The distribution of caddisflies and mayflies are not geographically restricted like the other aquatic groups These aquatic insects are more ecologically dependent on the water quality and substrata conditions rather than restricted by geographically barriers (Berner 1977 Berner and Pescador 1988)

Drainage Evolution within the Region

The current geography of the Coastal Plains probably originated during the Jurassic or early Cretaceous Era (Hack 1969 Hodler and Schretter 1986) Much of this region was formed as a submerged seabed and eroded landscape from the Appalachians (Hack 1969 Hodler and Schretter 1986) The region experienced periods of sealevel resurgences and withdrawals that continued into the Tertiary Period of the Cenozoic (Hack 1969) Geological evidence suggested that the ocean coastline of the coastal plains extended to the present day Fall Line of Alabama and Georgia (Hack 1969 Swift et al 1986)

The current geology exposed today was formed during the Tertiary Period of Cenozoic Era (Hodler and Schretter 1988). During the early Tertiary, the Atlantic Coastal Plain was relatively narrow because of the rise in sealevel. Another resurgence occurred in the latter part of the Tertiary during the Miocene Epoch. This resurgence caused the sea level to rise a hundred feet higher then its present day level (Hack 1969).

During the Tertiary Period of the Cenozoic, only a fraction of the current major rivers existed. These rivers were the Altamaha and Savannah Rivers of the Atlantic Coastal Plain and the Alabama and Chattahoochee Rivers of the Gulf Coastal Plain (Swift et al. 1986). The Chattahoochee River is believed to be the oldest river within the region because of its Triassic deposits (Campbell 1896). The other major rivers within the region have been present since the Eocene (Johnson 1905, Campbell 1896). The smaller river drainages such as the Blackwater, Choctawhatchee, Escambia, and Yellow Rivers were reduced or nonexistent because of the inundation of the areas by the sea (Swift et al. 1986). However, it was not until the Pliocene that the Ogeechee, Satilla, and the St. Mary's Rivers were formed (Hodler and Schretter 1986).

The Quaternary Period of the Cenozoic Era also brought changes to the landscape due to sea level fluctuations. The advance and retreat of the continental ice sheets during this time lasted 2 million years. These glaciation events caused the sea levels to fluctuate several hundred feet, which affected the shape of Georgia's Coastal Islands and the Florida peninsula (Hodler and Schretter 1986). The current Florida coastline was formed during the latter part of this period. Throughout the history of the Gulf Coastal Plain, there have been numerous stream migrations along the Atlantic slope resulting in an unsymmetrical condition of the stream basins (Campbell 1996). The condition is known as lateral stream migration. Lateral stream migration describes the phenomenon of the uneven distribution of tributaries that exist in the Conecuh River of the Escambia system and the Flint River of the Apalachicola system (Price and Whetstone 1977)

Stream migrations have been documented for the Gulf and Atlantic Coastal Rivers since the Tertiary Hayes and Campbell (1897) suggested that the Chattahoochee River was captured by the Etowah River of the Coosa-Alabama River system during the Tertiary The middle portion of the Chattahoochee River retained its southerly course because it was entrenched by the uplift known as the Chattahoochee Arch (Campbell 1897) During the Pliocene-Pleistocene Epochs of the Tertiary the rivers east of the Chattahoochee River deflected in a southeasterly direction (Price and Whetstone 1977) The western streams such as the Pea River of the Choctawhatchee and the Conecuh of the Escambia turned southward away from the Chattahoochee River This southward deflection of streams was noted in geological deposits of the Miocene and Pliocene ridges (Swift et al 1986)

The Atlantic Coastal rivers were affected by stream capture of the Gulf Coastal Rivers of the Tennessee and Alabama during the Tertiary Period Geological evidence indicated that tributaries of the Etowah River were captured by the Chattahoochee River (Campbell 1897) This was later followed by the capture of headwater tributaries of the Chattahoochee River by the upper Savannah River near Tallulah Falls (Campbell 1897)

Evolution of the Southeastern Freshwater Fauna

Based on fossil evidence the pleurocerid genus *Elimia* have inhabited North American rivers since the Jurassic (White 1891 Yen 1948) However *Elimia* could only have existed in the Atlantic and Gulf Coastal Plains since the Pliocene This is substantiated by the discovery of a Pliocene freshwater fossil deposit on the Satilla River that is directly below the Altamaha River in Georgia (Aldrich 1911). This Pliocene site contains many genera of the recent freshwater fauna including *Elimia*. These *Elimia* were originally identified as *Potamides satillensis* by Aldrich (1911). However, Thompson and Hershler (1991) believe the snails to be *Elimia*. Notably, the current fauna of the Satilla River is devoid of freshwater gastropods probably due to a post-Pliocene change in water quality associated with the erosion of carbonate deposits (Thompson and Hershler 1991).

The dispersal and speciation of the freshwater fish, mollusk, and turtles within the Atlantic and Gulf Coastal rivers was predicted to occur during the Pliocene or early Pleistocene (Thompson 1977, Swift et al. 1986, Lamb et al. 1996, Roman 1997). Swift et al. (1977) argued that many species reached the Atlantic Coastal Rivers by stream capture and speciated after reaching these rivers or *in situ*. The high number of endemic species in these drainages also suggests that speciation probably occurred after these ancestral stocks had colonized the river basins (Thompson 1977, Hobbs 1981, Lamb et al. 1996).

The time of species divergence of the southeastern *Elimia* can be estimated using mitochondrial DNA as a molecular clock. A conservative estimate of the mtDNA CO1 is predicted to occur at a relative rate of sequence divergence of 1-3% per million years between lineages (Moritz et al. 1997). Because the mitochondrial DNA of many animals is maternally inherited and has the same metabolic function across most taxa, one can approximate the time of divergence of a group of species (Bermingham 1990). The divergence rate calculated for the Atlantic Coastal rivers and Apalachicola River *Elimia* species in this study was from 9-20%. This finding suggests that the *Elimia* of the Atlantic slope had speciated prior to the Pliocene from betwen 9-60 million years ago More molecular data is needed to approximate the time of divergence for the other Gulf Coastal river *Elimia*

Biodiversity Loss and Conservation Implications

The Decline of Aquatic Mollusks

Since the beginning of this century there has been a noticeable decline in the number of mollusk species their abundance and available habitat within North American rivers (Brower 1971 Harman 1974 Gordon et al 1992 Williams et al 1992a 1993, Lydeard and Mayden 1995 Freeman et al 1996 Righter et al 1997) Currently, 31 species and 2 subspecies of snails are presumed extinct in the Alabama River system (Bogan et al 1995) The majority of these snail extinctions are in the pleurocerids Fourteen of these extinct species are *Elimia* (Lydeard and Mayden 1995) Also within the Mobile Basin 47 snail species are listed as endangered and 17 species are considered threatened (Lydeard and Mayden 1995)

Within this area there has been a considerable reduction in suitable habitat for mollusks Within the Chattahoochee River, a second major tributary of the Apalachicola River *Elimia* species survive only in a few isolated tributaries The tributaries surveyed along the Flint River in this study also revealed a noticeable decline in the *Elimia* populations Many of these populations have been extirpated nearby Lake Blackshear a Reservoir west of Cordele Georgia Tributaries that are located upstream from the reservoir are constantly inundated with slow-moving water from the hydroelectric dam

Threats to the Aquatic Ecosystems

The causes of mollusk extinctions in this century have been attributed to the destruction of riverine habitats by urbanization and agricultural activities Because gastropods have limited mobility, snails are extremely vulnerable to habitat perturbations Since the beginning of the 1900's, researchers have seen many freshwater mollusk species dwindle to reduced numbers or to extinction (Ortmann 1909; Williams et al 1992a 1992b) The primary causes for these extinctions are impoundments siltation channelization pollution excess nutrients surface runoff and the introduction of nonindigenous species (Brower 1971 Harman 1974 Gordon et al 1992 Williams et al 1992a 1993, Lydeard and Mayden 1995, Freeman et al 1996 Righter et al 1997)

River impoundments or dams have been documented to be a major cause of the demise of mollusk species These impoundments have been used for flood control hydroelectric power navigation irrigation, urban water supplies and recreation (Brower 1971 Harman 1974 Gordon et al 1992) Impounded waterways have drastically affected the aquatic ecosystems of rivers by altering their physical chemical and biological environments (Brower 1971 Harman 1974 Gordon et al 1992 Williams et al 1992a 1993) Impoundments alter rivers by increasing siltation reducing suitable streambed substrates restricting water flow reducing dissolved oxygen levels and increasing drift material after dewatering (Harman 1974, Layzer et al. 1993 Williams et al. 1992a 1993 Neves 1997) The stream habitats most affected by dams are the riffle and shoal areas (Layzer et al 1993) These shoal regions are the primary habitat of pleurocerid snails i e *Elimia* in the rivers of Alabama and Georgia

Another severe effect of impoundments is siltation (Harman 1974). Increased silt clogs the respiratory system. Excessive silt acts as an abrasive agent that erodes the periostracum layer of the mollusk shell (Harman 1974). Once the periostracum is worn away, the remaining shell layers dissolve. The dissolution of the shell ultimately leads to mortality (Harman 1974).

A second severe effect of impoundments is the reduction of available substrate. The impoundment of rivers reduces the available substrate for the normal life cycle of snails. Since mollusks are benthic dwellers, the streambed substrate determines the species composition. Streambeds that are composed of a number of components such as stones, gravel and sand support the greatest number of species (Clench and Turner 1956). A study conducted by Blair and Sickel (1986) showed that pleurocerid gastropods were not found at the mouth of rivers which consisted mostly of mud and silt substrate. However, many snail species use a mixture of sand and silt for their reproduction and feeding. Some gastropods which include *Elimia* are grazers that feed on the detritus material mixed in with the sand and silt.

Reduced water flow produced by impoundments also effects aquatic mollusks by reducing the dissolved oxygen levels. Many aquatic mollusks require fast moving currents for respiration and filter feeding. By restricting the water flow, reservoirs or lake environments are created (Neves et al. 1997). These lotic environments have decreased dissolved oxygen and increased sedimentation. Most river mollusks are not found in lakes because of their higher oxygen requirements. This stringent requirement makes it extremely difficult to keep pleurocerids in captivity.

Mollusks are greatly effected by periods of low dewatering by dams. Periods of low dewatering increased the likelihood that stranded mollusks would enter the drift material The shoal areas that would normally be underwater become exposed by the reduction in discharge volume The mollusks residing in these areas become stranded (Layzer J B et al 1989) Studies by Perry & Perry (1986) and Layzer et al (1983) demonstrated that exposed organisms are more likely to become part of the drift material after the water flow level was increased by the dam. Exposed snails typically died of desiccation due to being stranded

Biodiversity Conservation

A decline in biodiversity can also result from the loss of populations that contain unique genetic and phenotypic traits (Meffe and Carroll 1994) Currently, conservation biology is also focusing on the protection of population level variation within a species. This concept is thought to be beneficial to the species long term survival (Meffe and Carroll 1994 Williams and Mulvey 1994) Both Meffe and Carroll (1994) and Williams and Mulvey (1994) state that the critical evolutionary and ecological unit is the population. A widely distributed species may consist of genetically isolated populations that may function at different roles in different systems (Meffe and Carroll 1994) This crucial role of the individual population may be overlooked if all the populations were lumped under the same species name Both parties argue that the persistence of populations within a local system is more important than the persistence of the species Meffe and Carroll (1994) believe that the loss of global biodiversity has also resulted from the loss of populations and as well as species So conservation that is focused primarily on the preservation of species does not address the entire problem of biodiversity loss

Habitat Conservation

Conservationists believe the larger problem faced by gastropods at the present day is the loss of essential habitats and ecosystems (Maffe and Carroll 1994). In order to protect freshwater gastropods, the listing of species as endangered, threatened or special concern is not enough. This type of action would benefit organisms subjected to hunting or poaching. However, aquatic snails are not affected by either activity. The answer lies with protecting the aquatic habitat and the adjacent terrestrial environment known as the riparian community.

The major threat to aquatic ecosystems is the destruction of riparian community (Folkerts 1997). These regions filter the amount of sediment, excess nutrients, and toxic chemicals, providing a buffer zone for the river (Freeman et al. 1997). This buffer zone also reduces fluctuations in water temperature by limiting sunlight exposure for the stream (Freeman et al. 1997).

The preservation of the riparian community is essential to the overall health and well-being of aquatic ecosystems (Freeman et al. 1997, Folkerts 1997). This community influences surface water quality by controlling the amount of organic and inorganic sediments carried by streams (Stednick 1988). The sediment load of streams is controlled to a large extent by riparian habitats.

The destruction of the riparian vegetation also leads to the accelerated erosion along the riverbanks. This accelerated erosion increases the amount of sedimentation in the watershed. It is the riparian vegetation that maintains and promotes bank stability by trapping the soil within the root systems (USDI 1984). Accelerated erosion is the result of poor practices in land management which allow agricultural and urban use of riverbanks. By allowing this practice to continue, the end result would evenutally this to be true (Brower 1971 Harman 1974 Gordon et al 1992 Williams et al 1992a 1993 Lydeard and Mayden 1995 Freeman et al 1996 Righter et al 1997)

Certain conservation measures need to be implemented in order to protect habitats essential to the southeastern *Elimia* These measures are the restoration of riparian communities and the cessation of building any new hydroelectric dams The restoration and protection of the riparian communities will prevent soil erosion and sediment loss from entering the rivers Also the preventation of building new dams will help conserve the remaining fauna in these vital ecosystems

APPENDIX A
VOUCHER SPECIMEN INFORMATION

Appendix A is organized geographically from west to east for the Gulf Coastal river drainage systems and from north to south for the Atlantic Coastal river drainage systems within the study. Within each river, the voucher numbers are listed in ascending numerical order. The voucher specimens are labeled accordingly--FLMNH (UF) and the Museum of Comparative Zoology at Harvard (MCZ).

Alabama River Drainage System

UF 258432 *Elimia taitiana* U.S.A., Alabama, Monroe Co. Limestone Crk. 2.8 mi. E. of Drewery on SR 20 31°29.7'N 87°13.0'W FGT & E. L. Mihalcik, FGT 5624, 24 May 1996

UF 258433 *Elimia taitiana* U.S.A., Alabama, Monroe Co. Limestone Crk. 2 mi. N. of Drewery: 31°30.2'N 87°14.2'W FGT & E. L. Mihalcik, FGT 5625 24 May 1996

UF 258435 *Elimia taitiana* U.S.A., Alabama, Monroe Co. Alabama River Drainage small tributary to Mill Crk. ca. 5 mi. WSW of Monroeville 31°31.8'N 82°25.8'W FGT & E. L. Mihalcik FGT 5628, 24 May 1996

UF 258442 *Elimia taitiana* U.S.A., Alabama, Clarke Co. spring run of Rebbit Crk on AL Hwy 10, 7.5 mi. NE of Jackson FGT & E. L. Mihalcik, FGT 5629, 25 May 1996

UF 258441 *Elimia taitiana* U.S.A. Alabama Clarke Co. Fred T. Simpson Wildlife Refuge Limestone Crk FGT & E. L. Mihalcik FGT 5628 25 May 1996

MCZ 236204 *Goniobasis taitiana* U.S.A. Alabama Clarke Co. Branch of Rebbit Crk, 4.1 mi. W of Walker Spring Ex. H. D. Athearn 18 Feb 1967

Escambia River Drainage System

UF 241091 *Elimia* sp. "A" MS U.S.A. Alabama Escambia Co. Burnt Corn Crk. W of Brewton on SR 29 E. L. Raiser ELR 107 25 Nov 1994

UF258416 *Elimia* sp. "A" MS U.S.A. Alabama, Conecuh Co. Debra W. McIntyre Spring along side crk. 8.4 mi. WSW of Evergreen 31°25.8'N 87°08.8'W FGT & E. L. Raiser FGT 5622 23 May 1996

UF258431 *Elimia* sp. "A" MS U.S.A. Alabama Conecuh Co. Debra W. McIntyre Spring along side crk, 8.4 mi. WSW of Evergreen 31°25.8'N 87°08.8'W FGT & E. L. Raiser FGT 5622 23 May 1996.

Sepulga River

UF 224282 *Elimia* sp. "A" MS U.S.A. Alabama Conecuh Co. Sepulga River at US Hwy 31 F. G. Thompson, FGT 5241 23 May 1993

UF 224265 *Elimia* sp. "A" MS U.S.A. Alabama, Conecuh Co. creek, 7.5 mi. E of Evergreen 2.3 mi. NE of intersection Hwys 31 & 84 F. G. Thompson FGT 5242 23 May 1993

UF 224286 *Elimia* sp "A" MS U S A Alabama Conecuh Co Pigeon Crk at US Hwy 84, ca 16 mi E of Evergreen F G Thompson FGT 5243 23 May 1993

UF 224290 *Elimia* sp "A" MS. U S.A Alabama Escambia Co., Sepulga River at Brooklyn FGT & E L Raiser FGT 5244 24 May 1993

UF 224598 *Elimia* sp "A" MS U S.A Alabama, Escambia Co small creek 8 4 mi S of Brooklyn trib to Sepulga River FGT & E L Raiser, FGT 5245 24 May 1993

UF 241101 *Elimia* sp "A" MS U S.A Alabama, Escambia Co creek 5 3 mi N of SR 43 Gin Creek, 2 2 mi S of Brooklyn, E L Raiser ELR 110 25 Nov 1994

UF 241103 *Elimia* sp "A" MS U S A Alabama Escambia Co, Amos Mill Creek on SR 43 1 1 S of Brooklyn E L Raiser ELR 111 25 Nov 1994

UF 241106 *Elimia* sp "A" MS U S.A Alabama Conecuh Co., Bottle Crk, 2 5 mi NW of Brooklyn on SR 42 E L Raiser, ELR 112 25 Nov 1994

UF 241109 *Elimia* sp "A" MS , U S A Alabama Conecuh Co , Rawls Creek 4 7 mi NW of Brooklyn on SR 42 E L Raiser ELR 113 25 Nov 1994

UF 241111 *Elimia* sp "A" MS., U S A Alabama Conecuh Co creek 10 mi NW of Brooklyn on SR 42 (Horton Branch) E. L. Raiser ELR 114 25 Nov 1994

Conecuh River

UF 224278 *Elimia* sp "A" MS U S A Alabama Escambia Co 3 8 mi NW of Brewton on Hwy 41 at Burnt Corn Crk , E L Raiser & FGT ELR 020 05 Nov 1993

UF 224280 *Elimia* sp "A" MS U S.A Alabama Butler Co , Pigeon Creek, 10 7 mi E of Georgiana F G Thompson FGT 5240 23 May 1993

UF 241072 *Elimia* sp "A" MS U S.A Alabama Crenshaw Co 3 5 mi E of Rudledge on Patsaliga Crk off SR 10 E. L. Raiser ELR 097 05 Nov 1994

UF 241074 *Elimia* sp "A" MS , U S.A Alabama Crenshaw Co 23 7 mi W of Brantley on SR 106 on Patsaliga Crk. E. L. Raiser ELR 098 05 Nov 1994

UF 241075 *Elimia* sp "A" MS U S A Alabama Crenshaw Co 11 8 mi W of Brantley on SR 106 on Patsaliga Crk. E L Raiser ELR 099 05 Nov 1994

UF 241092 *Elimia* sp "A" MS U S.A Alabama Escambia Co. Burnt Corn Crk. W of Brewton on SR 29 E L Mihalcik ELR 107 05 Nov 1994

UF 241094 *Elimia* sp "A" MS , U S.A Alabama Escambia Co 20 3 mi E of Brewton at McGowin Bridge on the Conecuh River E L Raiser ELR 108 25 Nov 1994

UF 241097 *Elimia* sp "A" MS U S A Alabama Escambia Co crk 1 1 mi N of SR 29 on SR 43 (unnamed trib on Conecuh) E L Raiser, ELR 109 25 Nov 1994

UF 241098 *Elimia* sp. "A" MS. U.S.A. Alabama. Escambia Co. crk 1.1 mi. N of SR 29, on SR 43. (unnamed trib. on Conecuh) ELR 109. E. L. Raiser. ELR 109. 25 Nov 1994

UF 241112 *Elimia* sp. "A" MS. U.S.A. Alabama. Butler Co. Pigeon Creek. 10.7 mi. E of Georgiana. E. L. Raiser. ELR 115. 07 Jul 1995

UF 258430 *Elimia* sp. "A" MS. U.S.A. Alabama. Conecuh Co. crk 2.2 mi. SW of Evergreen on US Hwy. 31. FGT 8 E. L. Raiser. FGT 5621. 23 May 1996

UF 224288 *Elimia* sp. "A" MS. U.S.A. Alabama. Conecuh Co. crk 12.8 mi. W of Evergreen on US Hwy 84. 31°25.8'N. 87°08.8'W. FGT 8 E. L. Mihalcik, FGT 5623. 24 May 1996

Yellow River Drainage System

UF 241133 *Elimia* sp. "B" MS. U.S.A. Florida. Okaloosa Co. Murder Creek, tributary to Yellow River on SR 2. 4.5 mi. W of SR 85. E. L. Raiser. ELR 105. 24 Nov 1994

Choctawhatchee River Drainage System

UF 41471 *Elimia "densicostata" curvicostata* U.S.A. Florida, Holmes Co. 0.1 E of Ponce de Leon on SR 90. Jackson Spring. E. L. Mihalcik. ELM 184. 2 Jan 1997

UF 224184 *Elimia "densicostata" curvicostata* U.S.A. Florida. Washington Co. Vernon 2-3 mi. above Rt. 79 bridge. H. G. Lee. 14 Jul 1993

UF 224239 *Elimia dickinsoni* U.S.A. Florida. Jackson Co. 1 mi. W of Graceville in SR 2 of Holmes Creek. Elizabeth L. Raiser. ELR 011. 02 Oct 1993

UF 224241 *Elimia "densicostata" curvicostata* U.S.A. Florida. Holmes Co. 0.7 mi. E of Noma on SR 2 on Wrights Crk. Elizabeth L. Raiser. ELR 012. 02 Oct 1993

UF 224242 *Elimia dickinsoni* U.S.A. Florida. Holmes Co. 0.7 mi. E of Noma on SR 2 on Wrights Creek. Elizabeth L. Raiser. ELR 012. 02 Oct 1993

UF 224243 *Elimia "densicostata" curvicostata* U.S.A. Florida. Holmes Co. 5.7 mi. N of Bonifay on SR 79 on Wrights Creek. Elizabeth L. Raiser. ELR 013. 02 Oct 1993

UF 224244 *Elimia dickinsoni* U.S.A. Florida. Holmes Co. 5.7 mi. N of Bonifay on SR 79 on Wrights Creek, Elizabeth L. Raiser. ELR 013. 02 Oct 1993

UF 224247 *Elimia dickinsoni* U.S.A. Florida. Holmes Co. 4.3 mi. E of Bonifay at Holmes Co. line. SR 90 on Holmes Creek, Elizabeth L. Raiser. ELR 014. 03 Oct 1993

UF 224252 *Elimia clenchi* U.S.A. Florida. Holmes Co. 1.4 mi. W of Caryville on SR 90. Holmes Co. line on Choctawhatchee River. E. L. Raiser. ELR 015, 03 Oct 1993

UF 224254 *Elimia "densicostata" curvicostata* U.S.A., Florida, Holmes Co 0.1 mi. E of Ponce de Leon on SR 90 at Jackson Spring Elizabeth L. Raiser ELR 018 03 Oct 1993

UF 224259 *Elimia clenchi* U.S.A. Florida Walton Co Seven Run Crk. 2.4 mi N of Red Bay on SR 81 E. L. Mihalcik ELR 017 3 Oct 1993

UF 224270 *Elimia "curvicostata" densicostata* U.S.A. Florida Washington Co 0.8 mi. N of Vernon on Holmes Creek, Elizabeth L. Raiser ELR 018 03 Oct 1993

UF 224264 *Elimia* sp U.S.A. Florida Washington Co 1.2 mi W of Ebro on Washington Co line on SR 20 on Choctawhatchee River E. L. Raiser, ELR 018 03 Oct 1993

UF 224297 Elimia sp "B" MS U.S.A. Alabama, Geneva Co at Corner Creek, 8.7 mi WSW of Samson at Hwy 54 F. G. Thompson FGT 5247 24 May 1993

UF 222568 Elimia sp "B" MS U.S.A. Alabama Coffee Co Whitewater Creek at Lowry Mill, Coffee Co Rd #60 22 mi S of Troy, Monte McGregor 13 Sep 1993

UF 241077 *Elimia* sp "B" MS, U.S.A. Alabama Coffee Co 0.4 mi E of Elba on SR 189 on Pea River E. L. Raiser ELR 100 05 Nov 1994

UF 251669 *Elimia* sp "B" MS U.S.A. Alabama Geneva Co Choctawhatchee River 0.5 mi E of Geneva F. G. Thompson FGT 5548 04 Sep 1995

UF 263358 *Elimia dickinsoni* U.S.A. Florida Holmes Co Ponce de Leon State Recreation Area Ginger Clark ELM 128 19 Jun 1996

MCZ 98173 *Goniobasis curvicostata* U.S.A. Alabama Henry Co E fork of Choctawhatchee River 8 mi W of Abbeville Field No 968 Clench & Van der Schalie 24 Aug 1933

MCZ 98189 *Goniobasis mutabilis* U.S.A. Alabama Dale Co West Fork of Choctawhatchee River approx 7 mi E of Ozark, Clench & Vander Schalie Aug - Sep 1933

MCZ 99242 *Goniobasis curvicostata* U.S.A. Alabama Dale Co 9 mi S of Ozark L. Goodrich 1929

Apalachicola River Drainage System

Apalachicola River

UF 251634 *Elimia "curvicostata" densicostata* U.S.A. Florida Gadsden Co 1 mi E of Chattahoochee on North Mosquito Creek E. L. Raiser ELR 125 18 Jun 1995

UF 251639 *Elimia* sp, U.S.A. Florida Gadsden Co south of bridge on Apalachicola River W of Chattachoochee E. L. Raiser ELR 126 18 Jun 1995

UF 251641 *Elimia* sp. U.S.A. Florida. Gadsden Co., south of bridge on Apalachicola River, west of Chattahoochee. E. L. Raiser, ELR 126. 16 Jun 1995

Chipola River System

UF 224228 *Elimia "curvicostata" densicostata* U.S.A. Florida. Jackson Co. 1 mi. E of Marianne at Merritt's Mill Pond on SR 90 nr bridge. E. L. Raiser. ELR 007. 02 Oct 1993

UF 224229 *Elimia "curvicostata" densicostata* U.S.A. Florida. Jackson Co. 1.5 mi. NW of park entrance. Florida Caverns State Park on SR 168. In small creek. Elizabeth L. Raiser. ELR 008. 02 Oct 1993

UF 224230 *Elimia "curvicostata" densicostata* U.S.A. Florida. Jackson Co. 2.9 mi. NW of park entrance. Blue Spring Hole, spring run, Florida Caverns State Park, Elizabeth L. Raiser. ELR 009. 02 Oct 1993

UF 224235 *Elimia "curvicostata" densicostata* U.S.A. Florida. Jackson Co., 1.4 mi. N of Marianna on Chipola River off SR 168. Elizabeth L. Raiser. ELR 010. 2 Oct 1993

UF 241066 *Elimia dickinsoni* U.S.A. Alabama. Houston Co. 5.2 mi. N of Cottonwood on SR 55 on trib. of Cowart's Crk, E. L. Raiser. ELR 093. 07 Jul 1995

UF 241080 *Elimia dickinsoni* U.S.A. Alabama. Houston Co. 3.2 mi. E of Madrid on Big Crk, E. L. Raiser. ELR 101. 06 Nov 1994

UF 241084 *Elimia dickinsoni*, U.S.A. Alabama. Houston Co. 5.5 mi. E of Campbellton on Spring Creek, E. L. Raiser. ELR 102. 06 Nov 1994

UF 241128 *Elimia dickinsoni* U.S.A. Alabama. Jackson Co. 5.3 mi. E of Campbellton on SR 2 at Marshall Creek. E. L. Raiser. ELR 103. 06 Nov 1994

UF 251648 *Elimia "curvicostata" densicostata* U.S.A. Florida. Calhoun Co., Chipola R. 1 mi. E of Clarksville of Hwy 20 bridge. F. G. Thompson. FGT 5527. 04 Jul 1995

UF 263357 *Elimia curvicostata*, U.S.A. Florida. Jackson Co. Chipola R. at CR 167 (bridge to FL. St. Caverns Park). Paul Moler. ELM 129. 06 Jun 1996.

UF 263362 *Elimia curvicostata* U.S.A. Florida. Jackson Co., Chipola R. at SR 278 Paul Moler, ELM 131. 19 Jun 1996.

Flint River System

UF 41458 *Elimia "curvicostata" densicostata* U.S.A. Georgia. Crisp Co. Limestone Cr. Drayton Rd. 4.7 mi. S, 1.1 mi. E of Drayton. 32°01'08"N 83°54'39"W. E. L. Mihalcik & F. G. Thompson, ELM 159. 13 Oct. 1996

UF 230728 *Elimia viennaensis* U.S.A. Georgia. Dooly Co. Little Pennahatchee Creek 3.5 mi. NW of Vienna. F. G. Thompson & E. L. Raiser. FGT 5478. 30 Sep 1994

UF 241055 *Elimia viennaensis* U.S.A. Georgia Dooly Co. 3.5 mi NW of Vienna on SR 90 of Little Pennahatchee Creek E. L. Raiser & F. G. Thompson ELR 088 30 Sep 1994

UF 241058 *Elimia viennaensis* U.S.A. Georgia Upson Co., 5.6 mi SW of Lincoln Park on SR 36 of Flint River (shoal downstream of bridge) E. L. Raiser & F. G. Thompson ELR 089 01 Oct 1994

UF 241057 *Elimia viennaensis* U.S.A. Georgia, Upson Co., 5.6 mi SW of Lincoln Park on SR 36 of Flint River (shoal downstream of bridge) E. L. Raiser & F. G. Thompson, ELR 089 01 Oct 1994

UF 241059 *Elimia viennaensis* U.S.A. Georgia Upson Co., 5.6 mi SW of Lincoln Park on SR 36 of Flint River (shoal upstream of bridge) E. L. Raiser & F. G. Thompson ELR 090 01 Oct 1994

UF 241056 *Elimia viennaensis* U.S.A. Georgia Upson Co., 5.6 Mi SW of Lincoln Park on SR 36 of Flint River (shoal upstream of bridge) E. L. Raiser & F. G. Thompson, ELR 090 01 Oct 1994

UF 251611 *Elimia viennaensis* U.S.A., Georgia Upson Co., 7.1 mi. W of Thomaston on SR 36 on Potato Crk. F. G. Thompson & E. L. Raiser ELR 118 07 May 1995

UF 251612 *Elimia viennaensis* U.S.A. Georiga Upson Co., 7.1 mi W of Thomaston on SR 36 on Potato Creek F. G. Thompson & E. L. Raiser ELR 118, 07 May 1995

UF 251614 *Elimia viennaensis* U.S.A. Georgia Upson Co., 23 mi W of Thomaston on Adams Perry Rd. E. L. Raiser & F. G. Thompson ELR 116 07 May 1995

UF 251615 *Elimia viennaensis* U.S.A. Georgia Upson Co., 23 mi W of Thomaston on Adams Perry Rd E. L. Raiser & F. G. Thompson ELR 119 07 May 1995

UF 251616 *Elimia viennaensis* U.S.A. Georgia Upson Co., at Po Biddy Rd. Bridge on Flint R. F. G. Thompson & E. L. Raiser ELR 120 07 May 1995

UF 251617 *Elimia viennaensis* U.S.A. Georgia Meriwether Co., 4.6 mi E of Gay on SR 109 bridge on Flint River E. L. Raiser & FGT ELR 121 07 May 1995

UF 251619 *Elimia albanyensis* U.S.A. Georgia, Dougherty Co. Flint R. between Broad Ave. & Jefferson St. in Albany E. L. Raiser ELR 122 12 May 1995

UF 251625 *Elimia clenchi* U.S.A. Georgia Decatur Co. Bainbridge off SR 84 downtown city park E. L. Raiser ELR 124 17 Jun 1995

UF 251643 *Elimia viennaensis* U.S.A. Georgia Crisp Co. Limestone Creek, at Cannon Rd. 4.7 mi S of Drayton, 33°02'02"N 83°55'34"W F. G. Thompson & E. L. Mihalcik, FGT 5533 26 Aug 1995

UF 251649 *Elimia viennaensis* U.S.A. Georgia Dooly Co. Turkey Crk. 4.4 mi. NNE, 0.8 mi. E of Drayton F. G. Thompson & E. L. Mihalcik, FGT 5532 26 Aug 1995

UF 251650 *Elimia viennaensis* U.S.A. Georgia, Crisp Co. Limestone Crk. at Drayton Rd. 4.7 mi. S 1.1 mi. E of Drayton 32°01'08"N 83°54'38"W F. G. Thompson & E. L. Mihalcik, FGT 5534 26 Aug 1995

UF 251651 *Elimia "curvicostata" densicostata* U.S.A. Georgia Dooly Co., Limestone Creek at McCay Rd. ca. 4 mi. S 2 mi. E of Drayton, 32°02'00"N 83°54'33"W F. G. Thompson and E. L. Reiser FGT 5535 26 Aug 1995

UF 251653 *Elimia viennaensis* U.S.A. Georgia Dooly Co. Limestone Creek, at McCay Rd. ca. 4 mi. S 2 mi. E of Drayton 32°02'00"N 83°54'33"W F. G. Thompson & E. L. Reiser FGT 5535, 26 Aug 1995

UF 251656 *Elimia "curvicostata" densicostata* U.S.A. Georgia Crisp Co., Swift Crk approx. 4 mi. E of Warwick FGT 5536 26 Aug 1995

UF 251658 *Elimia viennaensis* U.S.A. Georgia Crisp Co. Swift Creek, ca. 4 mi. E. of Warwick F. G. Thompson & E. L. Mihalcik, FGT 5536 26 Aug 1995

UF 251660 *Elimia "curvicostata" densicostata* U.S.A. Georgia Crisp Co. Big Abrams Creek 4.2 mi. S of Oakfield F. G. Thompson & E. L. Mihalcik, FGT 5537 26 Aug 1995

UF 251662 *Elimia viennaensis*, U.S.A. Crisp Co. Big Abrams Creek, 4.2 mi. S of Oakfield F. G. Thompson & E. L. Mihalcik FGT 5537 26 Aug 1995

UF 251663 *Elimia "curvicostata" densicostata* U.S.A. Georgia Crisp Co. Swift Creek ca. 4 mi. E of Warwick, F. G. Thompson FGT 5538 27 Aug 1995

UF 251664 *Elimia "curvicostata" densicostata* U.S.A. Georgia Crisp Co. North Branch Swift Creek, 3.5 mi. W of Pateville F. G. Thompson FGT 5539 27 Aug 1995

UF 251665 *Elimia "curvicostata" densicostata* U.S.A. Georgia Crisp Co. Jones Crk. 2 mi. SE Oakfield Fred G. Thompson FGT 5540 27 Aug 1995

UF 251668 *Elimia viennaensis* U.S.A. Georgia Crisp Co., Jones Crk. 2 mi. SE of Oakfield F. G. Thompson FGT 5540 27 Aug 1995

UF 251982 *Elimia "curvicostata" densicostata* U.S.A. Georiga Crisp Co. Big Abrams Crk., 4.2 mi. S of Oakfield F. G. Thompson & E. L. Mihalcik, FGT 5537 26 Aug 1995

UF 263094 *Elimia albanyensis* U.S.A., Georgia Baker Co. Ichawaynochaway Crk, below dam 31°19.1N 84°29.3'W F. G. Thompson & E. L. Mihalcik, FGT 5630 08 Oct 1996

UF 263095 *Elimia albanyensis* U.S.A. Georgia Baker Co. Ichawaynochaway Crk, ca. 2 mi. below Hwy 91 bridge 31°11.9N 84°29.0'W E. L. Mihalcik FGT 5631 06 Jun 1996

UF 263098 *Elimia albanyensis* U S.A. Georgia Baker Co Ichawaynochaway Crk, ca 0.7 mi. above Flint River 31°10 5'N 84°28 2'W, E L Mihalcik, FGT 5632 08 Jun 1996

UF 266250 *Elimia viennaensis* U S.A. Georgia Dooly Co Limestone Crk. at McCay Rd , ca 4 mi S. 2 mi E of Drayton 32°02 00"N 83°54 33"W F G Thompson & E. L. Mihalcik, FGT 5535 26 Aug 1995

Chattahoochee River System

UF 41462 *Elimia ucheensis* U S A Alabama Russell Co Little Uchee Crk., 8.3 mi NE of Seale on Hwy 431 32°22 9'N 85°05 0'W E. L. Mihalcik & F G Thompson ELM 161, 30 Nov 1996

UF 41465 *Elimia ucheensis* U S.A Alabama Russell Co Little Uchee Crk. 8 3 mi NE Seale on Hwy 431 32°22 9'N 85°05 0'W. E. L. Mihalcik & F G Thompson, ELM 161, 30 Nov 1996.

UF 41467 *Elimia ucheensis* U S A Alabama Russell Co small creek on Hwy 431. 6 2 mi NE of Seale 32°21 6 N 85°06 5'W E. L. Mihalcik & F G Thompson ELM 162 30 Nov 1996

UF 41468 *Elimia ucheensis* U S A Alabama Russell Co small creek on Hwy 431 6.2 mi NE of Seale 32°21 6 N 85°06 5'W E L. Mihalcik & F G Thompson ELM 162, 30 Nov 1996

UF 41469 *Elimia ucheensis* U S.A Alabama Russell Co sm cr on Hwy 431 6 2 mi. NE of Seale 32°21 6 N 85°06 5'W. E. L. Mihalcik, ELM 162 30 Nov 1996

UF 41470 *Elimia ucheensis* U S A Alabama Russell Co 18 2 mi SW of Phenix City at Little Uchee Cr on SR 169 7 6 mi NE of Seale 32°22 7 N 85°10 9'W E. L. Mihalcik & F G Thompson ELM 163 30 Nov 1996

UF 251623 *Elimia ucheensis*, U S A Alabama Russell Co 18 2 mi SW of Phenix City at Little Uchee Creek on SR 169 E. L. Reiser, ELR 123 13 May 1995

MCZ 217369 *Elimia curvicostata* U S A Alabama Russell Co Uchee Crk at Rt 165 Ft. Mitchell Ex. H D Athearn 24 Sept. 1955

Atlantic Coastal River Drainage Systems

Savannah River System

UF 41444 *Elimia* sp U S.A Georgia Screven Co Beaverdam Cr 4 3 mi NNE of Sylvania on Hwy 301 E L Mihalcik ELM 150 14 Sep 1996

UF 41448 *Elimia bentoniensis* U S.A. Georgia Columbia Co lock & dam on Savannah R 3 km NW of Augusta 33°33 N 82°08 4'W E L Mihalcik ELM 152 14 Sep 1996

UF 231152 *Elimia sp.*, U.S.A. Elbert Co. Broad River at GA Hwy 17. F. G. Thompson & E. L. Raiser. FGT 5590. 22 Oct 1995.

UF 231153 *Elimia sp.* U.S.A. Elbert Co. Broad River at GA Hwy 17. F. G. Thompson & E. L. Raiser. FGT 5590. 22 Oct 1995.

UF 263322 *Elimia catenana*, U.S.A., Georgia. Screven Co. Beaver Dam Crk. 4.3 mi. NNE of Sylvania at US Hwy 301. F. G. Thompson & E. L. Mihalcik, FGT 5682. 09 Oct 1996.

UF 263330 *Elimia bentoniensis*. U.S.A. Georgia. Columbia Co., lock & dam on Savannah R., 3 km NW of Augusta. 33°33 N. 82°06.4'W. F. G. Thompson & E. L. Mihalcik, FGT 5684. 14 Sep 1996.

Ogeechee River System

UF 232373 *Elimia postelli*. U.S.A. Warren Co. Ogeechee River at Jewell, F. G. Thompson & E. L. Raiser. FGT 5591. 22 Oct 1995.

UF 266249 *Elimia postelli*. U.S.A. Georgia. Bullock Co. ca. 8 mi. from Statesboro on the Ogeechee R. E. L. Mihalcik, ELM 149. 13 Sep 1996.

Altamaha River System

Oconee River

UF 41450 *Elimia postelli*. U.S.A. Georgia. Laurens Co. Rocky Crk. 5.1 mi. SE of Dudley at CR 338. 32°28.4 N. 83°05.4'W. E. L. Mihalcik & F. G. Thompson. ELM 153 & FGT 5696. 11 Oct 1996.

UF 41451 *Elimia* sp. "C" MS. U.S.A. Georgia. Laurens Co. Rocky Crk. 8.7 mi. SE 2.9 mi. NW of Dudley at SR 328. E. L. Mihalcik & F. G. Thompson. ELM 154. 11 Oct 1996.

UF 41452 *Elimia* sp. "C" MS. U.S.A. Georgia. Laurens Co. Rocky Crk. NW of Dexter 1.3 mi. S of Dudley on Hwy 338. 32°29.4 N. 83°07.3'W. E. L. Mihalcik & F. G. Thompson, ELM 155. 11 Oct 1996.

Ocmulgee River

UF 41453 *Elimia postelli*. U.S.A. Georgia. Pulaski Co. Tuscawhatchee Cr. 4.2 mi. WSW of Hawkinsville on CR 257. 32°14.4 N. 83°30.0'W. E. L. Mihalcik & F. G. Thompson. ELM 156. 12 Oct 1996.

UF 41456 *Elimia postelli*. U.S.A., Georgia. Dooley Co. Cedar Cr. 10.5 mi. WSW 1.0 mi. N of Hawkinsville. 32°12.3 N. 83°35.0'W. E. L. Mihalcik & F. G. Thompson. ELM 157. 12 Oct 1996.

UF 251609 *Elimia mutabilis* U.S.A. Georgia. Newton Co. 0.2 mi. W from SR 212 in Snapping Shoal Community. Ocmulgee at Snapping Shoals. E. L. Raiser & F. G. Thompson. ELR 117. 08 May 1995

UF 251667 *Elimia mutabilis*. U.S.A., Georgia. Newton Co. South River, Snapping Shoals. F. G. Thompson & E. L. Raiser. FGT 5542. 24 Aug 1995

UF 263347 *Elimia timida* U.S.A. Georgia. Pulaski Co. Mile Crk. 200-300 m. upstream from Ocmulgee R. ca. 1 mi. SE of Hawkinsville. 32°16.0'N, 83°27.7'W. F. G. Thompson and E. L. Mihalcik. FGT 5686. 15 Sep 1996

UF 266246 *Elimia timida* U.S.A. Georgia. Dooly Co. Mock Springs. 10.5 mi. N of Hawkinsville, 32°12.3'N, 83°35.0'W. E. L. Mihalcik, ELM 158. 12 Oct 1996.

UF 266247 *Elimia timida* U.S.A. Georgia. Pulaski Co. Mile Cr. 200-300 m. upstream from Ocmulgee R. ca. 1 mi. SE of Hawkinsville. 32°16.0'N, 83°22.7'W. E. L. Mihalcik. ELM 160. 12 Oct 1996

UF 266328 *Elimia timida* U.S.A. Pulaski Co. Big Tuscawhatchee Crk, at Burnt Bridge Rd. ca. 7 mi. W of Hawkinsville. 32°15.9'N, 83°35.2'W. F. G. Thompson. FGT 5713. 26 Oct 1996

UF 266330 *Elimia timida* U.S.A. Georgia. Pulaski Co. headwater spring seep of Big Tuscawhatchee Crk. ca. 8 mi. WSW of Hawkinsville along GA Hwy 230. 32°14.3'N, 83°38.3'W. F. G. Thompson. FGT 5712, 02 Oct 1996

UF 266328 *Elimia timida* U.S.A. Georgia. Pulaski Co. Big Tuscawhatchee Crk. at Burnt Bridge Rd. ca. 7 mi. W of Hawkinsville. 32°15.9'N, 83°35.2'W. F. G. Thompson. FGT 5713. 26 Oct 1996

UF 266330 *Elimia timida* U.S.A. Georgia. Pulaski Co. headwater spring seep of Big Tuscawhatchee Crk.. ca. 8 mi. WSW of Hawkinsville along GA Hwy 230. 32°14.3'N, 83°38.3'W. F. G. Thompson. FGT 5712. 02 Oct 1996

UF 266383 *Elimia timida*, U.S.A. Georgia. Dooly Co. Mock Springs. 10.8 mi. WSW 1.0 mi. N of Hawkinsville. 32°12.3'N, 83°35.0'W. F. G. Thompson. FGT 5702. 12 Oct 1996

UF 267264 *Elimia timida* U.S.A. Georgia. Pulaski Co. headwater spring seep of Big Tuscawhatchee Crk. ca. 8 mi. WSW of Hawkinsville. along GA Hwy 230. 32°14.3'N, 83°38.3'W. F. G. Thompson, FGT 5712. 28 Oct 1996

Other species and their localities

UF 267737 *Elimia olivula* Alabama Monroe Co Alabama River ca. 1.5 mi. downstream of U.S. Hwy 84, ca 300 m upstream from grain elevator Macolm Pierson and Wally Hoznagel, 10 Feb 1991

UF 238528 *Pachychilus obeliscus* Honduras Santa Cruz de Yojoa Dept. NW shore of Lago de Yojoa, Limestone Peninsula 14°55'30"N 88°02'05"W F. G. Thompson & J Polisar. FGT 5516 30 May 1994

APPENDIX B

MORPHOMETRIC ANALYSES OF THE SOUTHEASTERN *ELIMIA* USED IN THE CANONICAL DISCRIMINANT ANALYSIS

Appendix B contains the morphological datasets of the 10 populations used in the CDA. A list of the species identifications and localities within the river drainages are given. The variable L, 2nd L, W ApH ApL, ApW are measured in millimeters. The variable Angle is measured in degrees. The quantity was noted for the number of whorls (#WH) ribs and spiral chords on the body whorl (BW)and penultimate whorl of the spire (SpW). The variables PBW (Position on the Body Whorl) and PSPW (Position on the Penultimate Whorl) indicate the position of the spiral chords relative to the periphery of the whorl. The color of the shell and the presence of banding is also given.

Alabama River Drainage System

Goniobasis taitiana U.S.A. Alabama Clarke Co. Branch of Rabbit Crk, 4 1 mi., W of Walker Spring MCZ 236204

Escambia River Drainage System

Elimia sp "A" MS U.S.A. Alabama, Escambia Co. Sepulga River at Brooklyn FGT 6244 UF 224290

Yellow River Drainage System

Elimia sp "B" MS U.S.A. Florida Okaloosa Co. Murder Creek, tributary to Yellow River on SR 2 4 5 mi W of SR 85 ELR 105 UF 241133

Choctawhatchee River Drainage System

Elimia sp "B" MS U.S.A. Alabama Geneva Co. Choctawhatchee River 0 5 mi E of Geneva F G Thompson FGT 5548 UF 251689

Apalachicola River Drainage System

Elimia curvicostata densicostata U.S.A. Georgia Dooly Co., Limestone Creek at McCay Rd ca 4 mi. S 2 mi E of Drayton FGT 5535 UF 251661

Elimia viennaensis U.S.A. Georgia Crisp Co. Limestone Crk. at Drayton Rd 4.7 mi. S, 1 1 mi E of Drayton FGT 5534 UF 251650

Elimia ucheensis U.S.A. Alabama Russell Co. 18.2 mi SW of Phenix City at Little Uchee Creek on SR 169 ELR 123 UF 251623

Altamaha River Drainage System

Elimia sp "C" MS U.S.A. Georgia Laurens Co., Rocky Crk. 8 7 mi SE 2 8 mi NW of Dudley at SR 326 ELM 154 UF 41451

Elimia mutabilis U.S.A. Georgia Newton Co. 0.2 mi W from SR 212 in Snapping Shoal Community Ocmulgee at Snapping Shoals ELR 117 UF 251609

Elimia timida: U.S.A., Georgia, Pulaski Co., Mile Cr., 200-300 m upstream from Ocmulgee R., ca. 1 mi. SE of Hawkinsville. ELM 160, UF 266247

Elimia taitiana-MCZ 236204

L	2nd L	W	ApH	ApL	ApW	#Wh	Ribs	BW	PosBW	SpW	PosSpW	Color	Banding	Angle	Sculpture
15.7	13.5	7.2	6.0	7.9	3.7	4	0	0	0	0	0	GOLDEN BR	0	38.5	SMOOTH
13.2	11.1	6.0	5.2	5.9	3.7	4	0	0	0	0	0	GOLDEN BR	0	41.0	SMOOTH
17.3	14.8	7.9	6.9	7.7	4.6	5	0	0	0	0	0	GOLDEN BR	+	45.8	SMOOTH
14.3	12.5	7.4	6.1	7.1	3.7	4	0	0	0	0	0	GOLDEN BR	0	39.0	SMOOTH
16.8	14.4	7.8	6.3	6.7	4.1	3	0	0	0	0	0	GOLDEN BR	0	56.0	SMOOTH
12.8	10.2	6.5	7.0	7.9	4.8	5	4	0	0	0	0	BROWN	+	32.0	SMOOTH
16.5	15.3	8.8	5.8	6.2	3.4	5	0	0	0	0	0	GOLDEN BR	+	40.0	SMOOTH
13.3	10.9	8.4	7.1	7.8	4.9	4	0	0	0	0	0	GOLDEN BR	+	42.0	SMOOTH
11.5	10.1	5.1	5.8	6.2	3.4	5	0	0	0	0	0	GOLDEN BR	0	45.0	SMOOTH
13.7	12.6	6.9	5.8	5.9	3.7	4	0	0	0	0	0	GOLDEN BR	0	48.0	SMOOTH
19.9	16.1	5.2	8.9	7.9	4.7	4	0	0	0	0	0	GOLDEN BR	+	30.0	SMOOTH
14.7	12.3	6.9	5.8	6.2	3.8	5	0	0	0	0	0	GOLDEN BR	+	45.0	SMOOTH
14.9	13.8	7.4	6.1	7.2	4.8	4	0	0	0	0	0	GOLDEN BR	0	56.0	SMOOTH
13.5	11.3	6.9	5.5	6.4	3.7	5	0	0	0	0	0	GOLDEN BR	0	48.0	SMOOTH
13.9	12.1	6.9	5.7	6.7	3.7	4	0	0	0	0	0	GOLDEN BR	0	48.0	SMOOTH
16.4	13.5	7.4	6.1	7.8	4.1	5	0	0	0	0	0	GOLDEN BR	0	43.0	SMOOTH
15.5	12.3	6.9	6.0	6.7	3.7	6	0	0	0	0	0	BROWN	+	33.5	SMOOTH
12.4	10.8	6.9	5.8	6.7	3.7	4	0	0	0	0	0	GOLDEN BR	0	55.0	SMOOTH
15.4	13.4	6.9	5.7	6.2	3.8	4	0	0	0	0	0	GOLDEN BR	0	48.0	SMOOTH
8.0	7.0	4.8	3.7	4.1	2.2	6	0	2	APP	1	BP	GOLDEN BR	0	48.0	SMOOTH
11.1	9.5	5.4	4.8	4.9	2.3	6	0	0	0	1	BP	BROWN	+	55.0	SMOOTH
14.2	12.2	6.7	6.0	6.4	3.6	5	0	0	0	0	0	GOLDEN BR	0	42.0	SMOOTH
14.1	12.8	7.1	5.7	7.0	4.2	5	0	0	0	0	0	GOLDEN BR	0	45.0	SMOOTH
14.7	11.8	6.1	5.1	6.3	3.2	6	0	0	0	0	0	GOLDEN BR	0	41.0	SMOOTH
14.1	11.8	6.4	5.2	6.1	3.5	6	0	0	0	0	0	GOLDEN BR	0	38.0	SMOOTH
14.4	12.1	6.6	5.8	6.9	3.8	4.7	0.2	0.1		0.1			0	43.7	
2.2	2.0	0.9	0.7	0.8	0.6	0.9	0.8	0.4		0.3			0	7.1	

Elimia taitsina-MCZ 236204

W/L	ApH/L	ApW/ApH	ApW/ApL	ApL/L	W/2ndL	ApW/W	ApW/L
0.45	0.38	0.62	0.53	0.45	0.53	0.51	0.24
0.45	0.39	0.71	0.63	0.45	0.54	0.62	0.28
0.45	0.40	0.67	0.60	0.45	0.54	0.56	0.27
0.52	0.43	0.61	0.52	0.50	0.59	0.50	0.26
0.48	0.36	0.66	0.61	0.40	0.54	0.53	0.24
0.52	0.50	0.69	0.59	0.62	0.54	0.71	0.37
0.45	0.31	0.59	0.55	0.34	0.56	0.39	0.18
0.45	0.53	0.69	0.62	0.59	0.59	0.77	0.37
0.44	0.49	0.61	0.55	0.54	0.50	0.87	0.50
0.50	0.41	0.66	0.63	0.43	0.54	0.54	0.27
0.42	0.35	0.69	0.62	0.38	0.51	0.57	0.24
0.48	0.38	0.70	0.63	0.42	0.55	0.57	0.27
0.50	0.41	0.74	0.63	0.49	0.54	0.61	0.30
0.51	0.41	0.67	0.56	0.47	0.61	0.54	0.27
0.50	0.41	0.65	0.59	0.45	0.57	0.54	0.27
0.45	0.37	0.67	0.53	0.45	0.55	0.55	0.25
0.45	0.39	0.62	0.55	0.43	0.59	0.54	0.24
0.53	0.47	0.64	0.55	0.54	0.61	0.56	0.30
0.45	0.37	0.63	0.59	0.40	0.51	0.52	0.23
0.53	0.41	0.59	0.54	0.45	0.69	0.45	0.24
0.49	0.41	0.50	0.47	0.44	0.54	0.43	0.21
0.47	0.42	0.59	0.65	0.45	0.55	0.52	0.25
0.50	0.40	0.74	0.50	0.50	0.59	0.59	0.30
0.41	0.35	0.63	0.51	0.43	0.53	0.52	0.22
0.45	0.37	0.67	0.57	0.43	0.54	0.55	0.25
0.45	0.41	0.66	0.57	0.48	0.57	0.56	0.26
0.03	0.05	0.08	0.04	0.06	0.04	0.08	0.04

Elmia species "A"-FGT5244, UF 224290

L	2nd L	W	ApH	ApL	ApW	#Wh	Ribs	BW	PosBWC	BpW	PosBpW	Color	Banding	Angle	Sculpture
18.5	14.8	7.4	4.7	8.2	3.9	NA	0	4	1P 1BP	2	1BP	DK BR	+	28.0	SMOOTH
16.8	13.7	7.1	4.3	7.5	3.0	NA	0	2	1P 1BP	1	1BP	DK BP	(+)	29.0	SMOOTH
18.7	14.4	7.4	4.3	7.0	3.6	NA	0	2	1P 1BP	2	2BP	DK BP	(+)	27.0	SMOOTH
16.7	14.9	7.8	4.9	7.6	4.0	NA	0	2	1BP 1P	1	1BP	DK BP	(+)	38.0	SMOOTH
13.0	11.8	6.2	3.8	6.4	3.5	NA	0	2	1P 1BP	1	1BP	LT OLIV GR	+	39.0	SMOOTH
13.7	11.4	6.1	3.5	5.9	2.8	NA	0	2	1BP 1P	1	1BP	LT OLIV GR	+	40.0	SMOOTH
19.5	15.0	7.9	4.7	8.3	4.5	NA	0	2	1P 1BP	2	1BP 1AP	DK BR	+	34.0	SMOOTH
18.6	15.9	8.8	5.4	9.0	4.3	NA	0	2	1P 1BP	0	0	OL GR	++	34.0	SMOOTH
16.6	15.0	7.9	4.5	7.7	4.0	NA	0	2	1P 1BP	1	1BP	DK BR	+	34.0	SMOOTH
18.5	15.0	8.8	4.5	8.2	4.1	NA	0	3	1P 1AP 1BP	1	1BP	DK BR	+	30.5	SMOOTH
16.7	13.4	7.0	4.5	8.7	3.5	NA	0	2	1BP 1P	1	1P	DK BR	+	31.0	SMOOTH
14.2	11.6	5.8	3.7	6.4	3.5	NA	0	2	1BP 1P	0	0	DK BR	+	39.0	SMOOTH
12.3	10.8	6.8	3.8	6.5	3.5	NA	0	2	1BP 1P	1	1BP	OL GR	+	63.0	SMOOTH
13.8	11.1	6.0	3.5	8.8	3.9	NA	0	2	1P 1BP	1	1BP	LT BP	+	33.0	SMOOTH
14.5	12.1	6.3	3.7	6.4	3.9	NA	0	5	1P 3AP 1BP	1	1BP	LT BP		34.5	SMOOTH
16.4	13.4	7.1	4.3	7.2	3.8			2.4		1.1				38.2	
2.5	1.7	0.8	0.5	1.0	0.4			0.9		0.6				9.6	
18.1	15.3	8.9	0	0	0	NA	0	0	0	1	1BP	DK BP	+	34.5	SMOOTH
15.7	12.6	7.8	0	0	0	NA	0	2	1BP 1P	1	1BP	LT OLIV GR	+	34.0	SMOOTH
13.2	11.2	6.6	0	0	0	NA	0	2	1P 1BP	1	1BP	DK BP	+	38.0	SMOOTH
14.0	12.8	8.4	0	0	0	NA	0	2	1P 1BP	1	1BP	DK BR	+	35.5	SMOOTH
14.7	12.5	8.8	0	0	0	NA	0	2	1BP 1P	0	0.0	DK BR	+	40.5	SMOOTH
13.0	11.0	6.0	0	0	0	NA	0	2	1BP 1P	1	1BP	OL GR	-	36.5	SMOOTH
12.5	11.1	6.8	0	0	0	NA	0	3	1P 1AP 1BP	1	1AP	DK BR	++	38.0	SMOOTH
12.8	11.1	6.2	0	0	0	NA	0	3	1P 1BP 1AP	1	1BP	LT BR	+	50.0	SMOOTH
15.7	13.0	7.0						2.3		1.0				38.0	
2.5	1.7	0.8						0.8		0.8				7.8	

Elmis species "A"-FGT5244, UF 224290

W/L	ApH/L	ApW/ApH	ApW/ApL	ApL/L	W/2ndL	ApW/W	ApW/L
0.40	0.25	0.83	0.48	0.44	0.50	0.53	0.21
0.42	0.26	0.91	0.52	0.45	0.52	0.55	0.23
0.40	0.23	0.86	0.54	0.37	0.51	0.51	0.20
0.47	0.29	0.82	0.53	0.46	0.53	0.51	0.24
0.48	0.29	0.92	0.85	0.48	0.52	0.56	0.27
0.45	0.26	0.80	0.48	0.42	0.54	0.48	0.20
0.40	0.24	0.96	0.54	0.43	0.52	0.58	0.23
0.43	0.27	0.90	0.48	0.45	0.53	0.51	0.22
0.42	0.24	0.89	0.52	0.41	0.53	0.51	0.21
0.43	0.24	0.91	0.50	0.44	0.53	0.51	0.22
0.42	0.27	0.78	0.52	0.40	0.52	0.50	0.21
0.48	0.28	0.95	0.86	0.49	0.30	0.59	0.25
0.49	0.32	0.90	0.54	0.53	0.56	0.58	0.28
0.43	0.25	1.11	0.70	0.41	0.54	0.65	0.28
0.43	0.26	1.05	0.61	0.44	0.52	0.62	0.27
0.43	0.26	0.90	0.54	0.44	0.51	0.54	0.24
0.03	0.02	0.09	0.05	0.04	0.06	0.05	0.03
0.42					0.52		
0.48					0.59		
0.50					0.58		
0.48					0.53		
0.48					0.54		
0.48					0.55		
0.42					0.49		
0.03					0.05		

Elimia species "B"-ELR 105, UF 241133

L	2nd L	W	ApH	ApL	ApW	#Wh	Ribs	BW	PosBW	SpW	PosSpW	Color	Banding	Angle	Sculpture
17.8	14.4	7.7	7.5	8.7	4.1	8	14	1	P	0	0	olive gr	++	42.0	smooth
15.1	12.8	7.4	7.0	7.8	4.3	8	11	0	0	1	BP	olive gr	+	43.0	smooth
18.7	16.0	8.8	8.0	8.5	4.3	6	11	0	0	2	AP BP	olive gr	-	35.0	smooth
17.0	14.6	7.1	7.1	8.0	3.7	5	10	0	0	0	0	olive gr	+	38.0	smooth
11.8	8.3	6.8	6.0	6.8	3.3	4	14	0	0	0	0	olive gr	++	36.0	smooth
18.7	16.0	8.1	7.5	8.0	4.3	5	11	0	0	0	0	olive gr	+	29.0	smooth
16.9	14.9	7.8	7.1	7.7	4.1	5	11	3	P,AP BP	0	0	olive gr	++	42.0	smooth
9.9	8.0	5.1	4.8	5.4	2.8	7	10	0	0	0	0	olive gr	++	39.0	smooth
10.8	7.8	5.3	4.4	4.7	2.5	7	14	2	P BP	1	BP	olive gr	++	51.0	smooth
16.0	13.6	7.0	7.0	7.7	3.7	5	12	0	0	1	BP	olive gr	++	37.0	smooth
11.7	9.9	5.8	6.2	6.7	3.8	6	13	0	0	1	BP	olive gr	+++	47.0	smooth
15.7	14.2	7.0	7.5	8.8	3.8	4	11	0	0	1	BP	olive gr	-	43.0	smooth
15.1	12.8	6.9	6.7	7.3	3.7	5.8	11.8	0.5		0.8				39.9	
3.1	3.0	1.0	1.1	1.2	0.6	1.0	1.5	1.0		0.8				5.9	
19.7	15.9	8.3	NA	NA	NA	7	15	1	P	0	0	olive gr	-	37.0	smooth
20.0	19.1	7.9	NA	NA	NA	9	10	0	0	1	BP	olive gr	+	35.5	smooth
19.4	15.5	8.4	NA	NA	NA	5	11	0	0	0	0	olive gr	++	44.0	smooth
19.2	15.1	8.1	NA	NA	NA	4	10	0	0	2	P BP	olive gr	++	38.0	smooth
15.4	13.0	7.2	NA	NA	NA	5	14	0	0	0	0	olive gr	+	35.0	smooth
16.2	14.7	7.7	NA	NA	NA	8	11	0	0	0	0	olive gr	+	36.0	smooth
16.5	13.6	7.8	NA	NA	NA	9	11	0	0	0	0	olive gr	++	38.0	smooth
14.0	12.2	7.4	NA	NA	NA	5	13	0	0	0	0	olive gr	++	48.0	smooth
17.8	14.9	8.9	NA	NA	NA	8	17	0	0	0	0	olive gr	++	40.0	smooth
15.8	13.5	7.5	NA	NA	NA	4	13	0	0	0	0	olive gr	++	31.5	smooth
19.8	16.0	8.3	NA	NA	NA	7	11	1	BP	0	0	olive gr	+	31.5	smooth
15.3	14.0	8.4	6.8	7.0	3.8	5	?	0	0	2	BP	olive gr	++	40.0	smooth
19.0	16.2	8.4	7.5	8.2	4.4	5	?	0	0	0	0	olive gr	++	27.0	smooth
18.6	16.5	8.1	7.9	8.7	4.4	5	?	0	0	0	0	olive gr	++	42.0	smooth
9.7	8.2	4.9	4.2	4.7	2.5	4	?	1	BP	1	BP	olive gr	+	38.0	smooth
16.4	13.5	7.4				5.5	12.1	0.3		0.4				38.5	
2.9	2.9	0.9				0.9	1.8	0.7		0.7				5.6	

Elimia species "B"-FGT5548, UF 281886

L	2nd L	W	ApH	ApL	ApW	#Wh	Ribs	BW	PosBW	SpW	PosSpW	Color	Banding	Angle	Sculpture
23.2	20.0	10.1	9.9	10.3	5.5	4	0	0	0	0	0	TAN BR		17.0	SMOOT
19.9	17.2	9.2	9.0	9.4	4.3	4	0	0	0	0	0	TAN BR	-	28.5	SMOOT
18.1	16.7	8.1	8.0	8.7	4.5	3	0	0	0	0	0	TAN BR		33.0	SMOOT
17.1	15.7	8.3	7.9	8.7	4.4	3	0	0	0	0	0	TAN BR		23.0	SMOOT
11.2	9.9	6.1	5.6	6.5	3.1	5	0	2	P,BP	1	BP	TAN BR		59.8	SMOOT
14.3	13.4	7.4	6.9	7.4	3.9	3	0	0	0	0	0	TAN BR	-	59.0	SMOOT
17.9	16.3	8.9	7.9	8.7	4.7	3	0	2	P BP	1	BP	TAN BR	-	26.0	SMOOT
16.5	15.9	8.8	8.2	8.7	4.5	4	0	0	0	1	BP	TAN BR		26.0	SMOOT
14.3	13.3	7.7	7.2	7.8	3.9	3	0	0	0	0	0	TAN BR		45.0	SMOOT
17.9	16.0	9.2	7.8	8.7	4.4	3	0	0	0	1	BP	TAN BR		53.5	SMOOT
15.3	13.1	7.0	6.5	7.4	3.7	4	0	0	0	1	BP	TAN BR		46.0	SMOOT
16.3	15.0	8.0	7.5	8.1	4.2	3	0	0	0	0	0	TAN BR		44.5	SMOOT
17.2	15.6	8.5	8.3	8.9	4.8	3	0	0	0	1	BP	TAN BR		42.5	SMOOT
18.6	15.2	8.0	7.4	7.8	4.1	5	0	3	P,2BP	0	0	TAN BR	(+)	33.0	SMOOT
15.5	14.9	7.9	7.0	7.9	3.9	3	0	0	0	0	0	TAN BR		38.0	SMOOT
14.4	12.5	8.0	7.3	8.2	4.5	2	0	0	0	0	0	TAN BR	(+)	30.0	SMOOT
13.1	10.8	8.1	6.3	7.0	3.0	6	0	0	0	1	BP	TAN BR	++	45.0	SMOOT
10.8	8.7	5.8	5.0	6.6	2.7	6	0	0	0.0	1	BP	TAN BR	+	41.0	SMOOT
11.1	9.9	5.8	5.1	5.6	2.9	6	0	2	P BP	1	BP	GOLDEN BR		39.0	SMOOT
11.9	11.1	7.5	6.3	6.9	3.3	8	0	3	P BP	1	BP	GOLDEN BR		55.5	SMOOT
8.2	6.9	4.9	3.6	3.9	2.1	8	0	2	P BP	1	BP	GOLDEN BR	-	44.0	SMOOT
16.4	13.7	7.7	7.1	7.9	3.9	4.0	0.0	0.7		0.5				39.7	
3.5	3.2	1.3	1.4	1.5	0.9	1.2	0.0	1.1		0.5				11.6	
11.0	10.1	6.0	NA	NA	NA	5	0	1	P	0	0	GOLDEN BR	-	52.0	SMOOT
11.4	9.7	6.4	NA	NA	NA	7	13	2	AP P	1	BP	GOLDEN BR	-	32.0	SMOOT
10.3	8.8	6.0	NA	NA	NA	5	0	2	P BP	1	BP	GOLDEN BR		50.5	SMOOT
9.7	5.0	5.0	NA	NA	NA	5	0	2	P BP	1	BP	GOLDEN BR		41.0	SMOOT
14.7	12.8	7.4				4.2	0.5	0.6		0.6				40.4	
3.7	3.6	1.4				1.3	2.5	1.1		0.5				11.2	

Elimia species "B"-FGT5546, UF 251589

W/L	ApH/L	ApW/ApH	ApW/ApL	ApL/L	W/2ndL	ApW/W	ApW/L
0.44	0.41	0.56	0.51	0.44	0.51	0.52	0.23
0.47	0.46	0.46	0.48	0.48	0.63	0.47	0.22
0.45	0.48	0.50	0.48	0.54	0.49	0.56	0.25
0.49	0.46	0.56	0.51	0.51	0.53	0.53	0.26
0.54	0.50	0.55	0.48	0.56	0.64	0.51	0.26
0.52	0.46	0.57	0.53	0.52	0.55	0.53	0.27
0.50	0.42	0.62	0.54	0.49	0.55	0.52	0.26
0.48	0.45	0.56	0.53	0.48	0.53	0.54	0.25
0.54	0.50	0.54	0.50	0.55	0.58	0.51	0.27
0.49	0.44	0.56	0.51	0.49	0.52	0.54	0.25
0.46	0.44	0.54	0.50	0.48	0.53	0.53	0.24
0.49	0.48	0.56	0.52	0.50	0.53	0.54	0.26
0.49	0.48	0.55	0.52	0.52	0.54	0.54	0.27
0.43	0.39	0.55	0.53	0.41	0.53	0.51	0.22
0.51	0.48	0.56	0.50	0.50	0.53	0.49	0.25
0.63	0.51	0.62	0.55	0.57	0.72	0.50	0.31
0.47	0.48	0.48	0.43	0.53	0.56	0.49	0.23
0.54	0.46	0.54	0.46	0.52	0.67	0.47	0.25
0.52	0.46	0.57	0.52	0.50	0.60	0.50	0.26
0.64	0.53	0.52	0.49	0.56	0.48	0.44	0.28
0.56	0.44	0.58	0.54	0.48	0.70	0.46	0.28
0.50	0.48	0.55	0.50	0.51	0.57	0.51	0.26
0.06	0.03	0.04	0.03	0.04	0.07	0.03	0.02
0.55					0.56		
0.56					0.68		
0.56					0.70		
0.52							
0.51					0.56		
0.08					0.07		

Elimia viennensis-FGT5834, UF 251650

L	2nd L	W	ApH	ApL	ApW	#Wh	Ribs	BWSPC	PosBWC	SWSC	PosSpSC	Color	Banding	Angle	Sculpture
21.7	15.5	10.9	9.9	10.5	5.6	4	13	9	2AP P 2BP	2	2AP	GOLDEN BR	-	55.9	GS
21.9	19.5	8.9	9.1	9.2	5.2	4	19	4	3AP P	5	2AP P,2BP	GOLDEN BR	-	29.0	GS
20.7	19.4	9.1	7.7	8.9	4.8	5	13	19	3AP P 8BP	2	AP	GOLDEN BR	-	40.0	GS
20.3	17.3	9.6	9.2	9.2	4.9	4	13	2	AP	3	4AP P	GOLDEN BR	-	38.0	GS
21.4	19.7	10.3	9.9	8.9	4.9	4	17	2	AP	3	2AP BP	GOLDEN BR	-	37.5	GS
17.9	19.3	9.7	9.0	9.5	4.9	3	18	4	2AP P BP	2	4AP	GOLDEN BR	-	46.5	GS
19.1	15.9	9.0	7.8	9.5	4.7	5	13	9	3AP P 5BP	2	AP BP	GOLDEN BR	-	45.5	GS
19.9	19.0	13.0	9.7	9.7	4.9	3	13	4	2AP P BP	2	AP BP	GOLDEN BR	-	34.0	GS
21.3	18.0	13.5	8.3	9.8	8.9	4	19	9	4AP P,4BP	5	2AP,2BP P	GOLDEN BR	-	34.0	GS
21.9	18.0	19.0	8.9	9.8	4.9	4	15	0	5	3	2AP BP	GOLDEN BR	-	32.5	GS
19.9	15.9	9.4	9.5	9.8	4.7	5	19	11	4AP P 9BP	3	AP P BP	GOLDEN BR	-	44.0	GS
20.1	17.0	9.9	9.0	8.9	4.4	4	15	7	2AP P 4BP	2	AP	GOLDEN BR	-	33.0	GS
21.7	19.8	10.9	9.7	10.7	5.8	9	19	5	4AP P	4	2AP P BP	GOLDEN BR	-	33.5	GS
21.6	19.3	11.9	9.9	10.9	5.4	4	11	7	3AP P 3BP	4	2AP P BP	GOLDEN BR	-	38.0	GS
22.0	19.3	10.8	9.8	10.7	5.8	3	15	2	AP	3	2AP BP	GOLDEN BR	-	24.0	GS
18.7	19.8	8.9	9.2	8.9	4.4	4	15	7	4AP P 3BP	3	2AP P	GOLDEN BR	-	28.5	GS
23.7	19.9	11.0	10.5	11.9	5.9	5	13	2	2AP	4	3AP P BP	GOLDEN BR	-	40.0	GS
17.5	19.2	9.9	7.8	9.9	4.5	3	18	10	4AP P 5BP	9	3AP P BP	GOLDEN BR	-	22.0	GS
20.2	18.3	11.3	9.7	9.9	5.4	3	17	9	3AP P 5BP	5	2AP P 2BP	GOLDEN BR	-	32.0	GS
19.4	17.0	8.4	8.3	9.4	4.9	4	18	9	4AP P 4BP	5	2AP P 2BP	GOLDEN BR	-	38.0	GS
21.3	19.0	10.3	9.5	10.4	5.2	5	19	8	4AP P 3BP	4	2AP P BP	GOLDEN BR	-	47.5	GS
17.7	15.8	9.7	7.4	9.5	4.5	3	13	6	4AP P BP	2	AP	GOLDEN BR	-	37.5	GS
19.7	17.9	9.2	8.7	9.4	4.9	4	13	6	4AP P	8	2AP P 2BP	GOLDEN BR	-	34.5	GS
19.7	15.9	9.2	7.9	9.5	4.9	4	15	5	3AP P BP	4	2AP P BP	GOLDEN BR	-	36.0	GS
19.9	18.0	10.5	9.3	10.4	5.4	3	12	3	4AP	4	2AP P BP	GOLDEN BR	-	43.0	GS
20.3	17.5	9.9	8.6	8.9	5.0	4.0	14.6	5.9		3.4				38.9	
1.5	1.1	0.9	0.8	9.9	0.4	0.7	1.9	3.0		1.1				7.4	

Elimia viennensis-FGT5534 UF 281650

L	2nd L	W	ApH	ApL	ApW	#Wh	Ribs	BWSPC	PosBWC	SWSC	PosSpSC	Color	Banding	Angle	Sculpture
21.7	18.5	[illegible]	[illegible]	10.5	[illegible]	4	13	5	2AP P 2BP	2	2AP	GOLDEN BR		55.0	GS
21.6	18.5	[illegible]	8.1	[illegible]	5.2	4	18	4	3AP P	5	2AP P 2BP	GOLDEN BR		28.0	GS
20.7	18.4	[illegible]	7.7	[illegible]	[illegible]	5	13	16	3AP P 6BP	2	AP	GOLDEN BR	-	40.0	GS
20.3	17.3	[illegible]	8.2	8.2	[illegible]	4	13	2	AP	3	2AP P	GOLDEN BR	-	38.0	GS
21.4	18.7	10.3	[illegible]	[illegible]	[illegible]	4	17	2	AP	3	2AP BP	GOLDEN BR		37.5	GS
[illegible]	18.3	[illegible]	[illegible]	8.5	[illegible]	3	15	4	2AP P BP	2	2AP	GOLDEN BR		48.5	GS
18.1	[illegible]	[illegible]	7.6	[illegible]	4.7	5	13	[illegible]	3AP P 5BP	2	AP BP	GOLDEN BR		45.5	GS
[illegible]	18.0	10.0	8.7	[illegible]	4.8	3	13	4	2AP P BP	2	AP BP	GOLDEN BR		34.0	GS
21.3	[illegible]	10.5	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	4AP P 4BP	5	2AP 2BP,P	GOLDEN BR	-	34.0	GS
[illegible]	18.0	10.0	8.8	[illegible]	[illegible]	4	15	0	0	3	2AP BP	GOLDEN BR		32.5	GS
19.0	15.8	8.4	[illegible]	[illegible]	4.7	5	18	11	4AP P [illegible]	3	AP P BP	GOLDEN BR		44.0	GS
20.1	[illegible]	[illegible]	8.0	[illegible]	4.4	4	15	7	2AP P 4BP	2	AP	GOLDEN BR		33.0	GS
21.7	18.0	[illegible]	[illegible]	10.7	5.5	5	18	5	4AP P	4	2AP P BP	GOLDEN BR		33.5	GS
21.5	19.3	[illegible]	[illegible]	[illegible]	5.4	4	11	7	3AP P 3BP	4	2AP P BP	GOLDEN BR	-	38.0	GS
[illegible]	19.3	10.8	[illegible]	10.7	[illegible]	3	15	2	AP	3	2AP BP	GOLDEN BR	-	24.0	GS
18.7	[illegible]	[illegible]	[illegible]	[illegible]	4.4	4	15	7	3AP P 3BP	3	2AP P	GOLDEN BR		29.5	GS
23.7	[illegible]	11.0	10.5	[illegible]	[illegible]	5	13	2	2AP	4	2AP P BP	GOLDEN BR		40.0	GS
17.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	4AP P 5BP	[illegible]	3AP P BP	GOLDEN BR		22.0	GS
20.2	18.3	11.3	8.7	[illegible]	5.4	3	17	[illegible]	3AP P 5BP	5	2AP P,2BP	GOLDEN BR		32.0	GS
18.4	[illegible]	8.4	8.3	[illegible]	[illegible]	4	15	[illegible]	4AP P 4BP	[illegible]	2AP P,2BP	GOLDEN BR	-	30.0	GS
21.3	18.0	10.3	[illegible]	10.4	5.2	5	18	[illegible]	4AP P 3BP	4	2AP P BP	GOLDEN BR		47.5	GS
17.7	[illegible]	[illegible]	7.4	[illegible]	4.5	3	13	[illegible]	4AP P BP	2	AP	GOLDEN BR		37.5	GS
18.7	17.0	[illegible]	[illegible]	[illegible]	[illegible]	4	13	[illegible]	3AP P	[illegible]	2AP P 2BP	GOLDEN BR	-	34.5	GS
18.7	[illegible]	[illegible]	7.6	[illegible]	[illegible]	4	15	5	3AP P BP	4	2AP P BP	GOLDEN BR	-	38.0	GS
[illegible]	[illegible]	10.5	[illegible]	[illegible]	5.4	3	12	3	3AP	4	2AP P BP	GOLDEN BR	-	43.0	GS
20.3	17.5	[illegible]	8.8	[illegible]	5.0	4.0	14.6	5.8		3.4				36.6	
1.5	1.1	[illegible]	0.8	[illegible]	[illegible]	[illegible]	1.6	3.6		1.1				7.4	

Elimia viennaesis-FGT5534 UF 251650

W/L	ApH/L	ApW/ApH	ApW/ApL	ApL/L	W/2ndL	ApW/W	ApW/L
0.50	0.44	0.58	0.53	0.48	0.59	0.51	0.26
0.48	0.37	0.64	0.57	0.43	0.53	0.53	0.24
0.44	0.37	0.60	0.52	0.43	0.55	0.51	0.22
0.47	0.40	0.60	0.53	0.45	0.55	0.51	0.24
0.46	0.42	0.58	0.50	0.46	0.55	0.46	0.23
0.54	0.45	0.61	0.56	0.48	0.60	0.51	0.28
0.47	0.46	0.62	0.55	0.45	0.57	0.52	0.25
0.51	0.44	0.55	0.48	0.46	0.58	0.48	0.24
0.49	0.38	0.67	0.57	0.46	0.58	0.53	0.26
0.46	0.40	0.58	0.50	0.44	0.58	0.48	0.22
0.49	0.45	0.55	0.48	0.51	0.60	0.50	0.25
0.44	0.40	0.55	0.50	0.44	0.26	0.46	0.22
0.50	0.45	0.57	0.51	0.46	0.60	0.51	0.25
0.51	0.45	0.55	0.50	0.50	0.57	0.46	0.25
0.48	0.45	0.59	0.54	0.48	0.56	0.54	0.26
0.47	0.44	0.54	0.48	0.48	0.52	0.50	0.24
0.46	0.44	0.55	0.53	0.46	0.56	0.53	0.24
0.50	0.43	0.59	0.51	0.50	0.54	0.51	0.26
0.56	0.43	0.62	0.55	0.49	0.62	0.48	0.27
0.48	0.43	0.58	0.51	0.46	0.55	0.51	0.25
0.48	0.45	0.55	0.50	0.49	0.57	0.50	0.24
0.46	0.42	0.61	0.53	0.48	0.55	0.52	0.25
0.47	0.44	0.58	0.52	0.46	0.54	0.53	0.25
0.49	0.42	0.63	0.56	0.45	0.58	0.53	0.26
0.53	0.47	0.58	0.52	0.52	0.58	0.51	0.27
0.48	0.43	0.58	0.53	0.47	0.58	0.51	0.25
0.03	0.02	0.03	0.03	0.02	0.06	0.02	0.01

Elimia viennaensis-FGT6534 UF 281650

W/L	ApH/L	ApW/ApH	ApW/ApL	ApL/L	W/2ndL	ApW/W	ApW/L
0.50	0.44	0.56	0.53	0.48	0.59	0.51	0.26
0.45	0.37	0.64	0.57	0.43	0.53	0.53	0.24
0.44	0.37	0.60	0.52	0.43	0.58	0.51	0.22
0.47	0.40	0.60	0.53	0.45	0.55	0.51	0.24
0.48	0.42	0.55	0.50	0.48	0.55	0.48	0.23
0.54	0.45	0.61	0.56	0.48	0.60	0.51	0.26
0.47	0.40	0.62	0.55	0.45	0.57	0.52	0.25
0.51	0.44	0.55	0.49	0.48	0.56	0.46	0.24
0.49	0.39	0.67	0.57	0.46	0.58	0.53	0.26
0.48	0.40	0.55	0.50	0.44	0.58	0.48	0.22
0.49	0.45	0.55	0.49	0.51	0.60	0.50	0.25
0.44	0.40	0.53	0.50	0.44	0.26	0.49	0.22
0.50	0.45	0.57	0.51	0.49	0.60	0.51	0.25
0.51	0.45	0.55	0.50	0.50	0.57	0.49	0.25
0.49	0.45	0.59	0.54	0.49	0.56	0.54	0.26
0.47	0.44	0.54	0.49	0.48	0.52	0.50	0.24
0.45	0.44	0.53	0.53	0.48	0.59	0.53	0.24
0.50	0.43	0.59	0.51	0.50	0.54	0.51	0.26
0.50	0.43	0.62	0.55	0.49	0.62	0.48	0.27
0.48	0.43	0.59	0.51	0.48	0.55	0.51	0.25
0.48	0.45	0.55	0.50	0.49	0.57	0.50	0.24
0.49	0.42	0.61	0.53	0.48	0.55	0.52	0.25
0.47	0.44	0.58	0.52	0.48	0.54	0.53	0.25
0.49	0.42	0.63	0.56	0.45	0.58	0.53	0.26
0.53	0.47	0.58	0.52	0.52	0.58	0.51	0.27
0.49	0.45	0.58	0.53	0.47	0.56	0.51	0.25
0.03	0.02	0.03	0.03	0.02	0.06	0.02	0.01

Ellobia uchsenia-ELR 123, UF 251623

L	2nd L	W	ApH	ApL	ApW	#Wh	Ribs	BW	PosBW	SpW	PosSpW	Color	Banding	Angle	Sculpture
17.9	14.7	8.5	4.7	8.0	4.1	NA	0	2	1AP 1BP	1	1BP	OLIVE GR	0	37.0	SMOOTH
15.2	12.6	7.4	4.2	6.9	3.5	NA	0	4	1P 1BP 2AP	1	1BP	OLIVE GR	0	39.0	SMOOTH
17.1	14.5	8.1	4.7	7.8	3.9	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	38.0	SMOOTH
14.4	12.2	7.0	4.9	7.0	3.7	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	41.0	SMOOTH
17.9	14.9	8.5	4.9	8.0	3.9	NA	0	2	1BP 1P	1	1BP	OLIVE GR	0	35.0	SMOOTH
13.4	11.7	7.2	3.8	6.9	3.3	NA	0	4	1P 1AP 2BP	1	1BP	OLIVE GR	0	34.0	SMOOTH
14.9	11.4	6.9	4.1	6.4	4.3	NA	0	2	1BP 1BP	1	1BP	OLIVE GR	0	31.0	SMOOTH
13.8	11.1	6.4	3.9	6.0	3.3	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	40.0	SMOOTH
16.0	12.9	7.7	4.3	7.5	3.9	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	28.0	SMOOTH
15.4	13.3	7.7	4.7	7.4	3.9	NA	0	1	1P	1	1BP	OLIVE GR	0	42.0	SMOOTH
14.7	12.0	7.0	3.7	6.7	3.5	NA	0	3	1P 1AP 1BP	1	1BP	OLIVE GR	0	37.0	SMOOTH
18.6	14.8	8.9	4.7	8.0	4.9	NA	0	3	1P 1AP 1BP	1	1BP	OLIVE GR	0	44.0	SMOOTH
15.7	12.5	6.7	3.5	6.8	3.5	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	31.5	SMOOTH
14.0	11.5	6.2	3.5	6.2	3.1	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	34.0	SMOOTH
15.5	13.0	7.8	3.7	7.2	3.8	NA	0	2	1BP 1P	1	1BP	OLIVE GR	0	37.0	SMOOTH
14.6	11.7	6.8	3.8	6.2	3.3	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	41.0	SMOOTH
14.1	12.1	7.3	4.1	7.0	3.4	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	36.0	SMOOTH
14.9	11.7	7.8	3.9	6.4	3.5	NA	0	3	1P 1AP 1BP	1	1BP	OLIVE GR	0	35.0	SMOOTH
18.2	13.1	8.0	4.3	6.9	3.9	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	39.0	SMOOTH
13.4	10.9	6.0	2.9	6.2	3.0	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	37.0	SMOOTH
14.9	12.3	7.0	4.3	7.0	3.5	NA	0	4	1P 2BP 1AP	1	1AP	OLIVE GR	0	31.0	SMOOTH
13.3	11.9	7.0	3.9	6.6	3.5	NA	0	2	1P 1BP	2	1P 1BP	OLIVE GR	0	40.0	SMOOTH
14.3	11.7	7.2	4.3	6.7	3.7	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	32.0	SMOOTH
14.1	11.5	7.0	3.5	5.8	3.5	NA	0	3	1P 1AP 1BP	1	1BP	OLIVE GR	0	40.0	SMOOTH
15.1	12.5	7.3	4.1	6.9	3.7		0	2.4		1.04			0	38.2	
1.3	1.2	0.8	0.5	0.6	0.4		0	0.8		0.20			0	5.7	
14.8	12.8	7.5	NA	NA	NA	NA	0	2	1P 1BP	1	1BP	OLIVE GR	0	46.0	SMOOTH
15.0	12.6	7.3					0.0	2.4		1.0				38.6	
1.3	1.1	0.7					0.0	0.7		0.2				4.5	

Elmia uchoensis-ELR 123, UF 251623

W/L	ApH/L	ApW/ApH	ApW/ApL	ApL/L	W/2ndL	ApW/W	ApW/L
0.48	0.26	0.87	0.51	0.45	0.59	0.48	0.23
0.49	0.28	0.83	0.51	0.45	0.59	0.47	0.23
0.47	0.27	0.83	0.51	0.44	0.56	0.48	0.23
0.48	0.31	0.82	0.53	0.48	0.57	0.53	0.26
0.48	0.28	0.80	0.49	0.45	0.57	0.48	0.22
0.54	0.26	0.94	0.50	0.48	0.62	0.48	0.25
0.46	0.28	1.08	0.67	0.43	0.60	0.63	0.28
0.47	0.29	0.85	0.55	0.44	0.58	0.52	0.24
0.48	0.27	0.91	0.52	0.47	0.60	0.51	0.24
0.50	0.31	0.83	0.53	0.48	0.58	0.51	0.25
0.48	0.25	0.95	0.52	0.48	0.56	0.50	0.24
0.54	0.28	1.04	0.61	0.48	0.50	0.59	0.30
0.43	0.22	1.06	0.53	0.42	0.54	0.52	0.22
0.44	0.25	0.89	0.50	0.44	0.55	0.50	0.22
0.49	0.24	0.97	0.50	0.48	0.58	0.47	0.23
0.45	0.26	0.87	0.53	0.42	0.56	0.50	0.23
0.50	0.26	0.83	0.49	0.50	0.48	0.48	0.24
0.48	0.27	0.90	0.55	0.44	0.60	0.50	0.24
0.49	0.27	0.91	0.57	0.43	0.61	0.48	0.24
0.45	0.22	1.03	0.48	0.48	0.55	0.50	0.22
0.47	0.26	0.91	0.50	0.47	0.57	0.50	0.24
0.53	0.29	0.90	0.53	0.50	0.58	0.50	0.26
0.50	0.30	0.88	0.55	0.47	0.62	0.51	0.26
0.50	0.25	1.00	0.60	0.41	0.61	0.50	0.25
0.48	0.27	0.90	0.53	0.46	0.58	0.50	0.24
0.03	0.02	0.08	0.04	0.02	0.03	0.04	0.02
0.51					0.59		
0.48					0.58		
0.03					0.03		

Elimia species "C"-ELM 154 UF 41461

L	2nd L	W	ApH	ApL	ApW	#Wh	Ribs	BWSPC	ProBWC	SWSC	PosSpSC	Color	Banding	Angle	Sculpture
18.9	14.9	8.2	7.6	8.5	4.4	6	0	0	3AP P 5BP	1	BP	GOLDEN BR	+++	35.0	SMOOTH
20.7	16.2	9.0	8.9	9.9	4.9	7	0	1	AP	0	0	GOLDEN BR	++	45.0	SMOOTH
18.5	15.3	9.0	7.6	8.6	4.2	8	0	1	P	1	BP	GOLDEN BR	+++	43.0	SMOOTH
13.9	11.2	8.8	6.1	6.6	3.6	6	0	0	AP P 4BP	1	BP	GOLDEN BR	+	46.0	SMOOTH
17.2	14.3	9.0	7.5	8.5	4.3	6	0	3	P 2BP	2	AP BP	GOLDEN BR	+	46.5	SMOOTH
11.0	9.2	5.5	4.4	4.7	2.7	7	0	0	BP P 4BP	1	BP	GOLDEN BR	++	39.0	SMOOTH
9.7	7.7	5.9	4.4	4.9	2.7	6	0	0	2AP P 5BP	1	BP	GOLDEN BR	+	43.0	SMOOTH
9.9	7.5	4.9	3.7	4.3	2.5	6	0	2	P BP	1	BP	GOLDEN BR	++	40.0	SMOOTH
10.6	8.5	5.1	4.3	4.9	2.8	8	0	3	AP P BP	1	BP	GOLDEN BR	++	45.5	SMOOTH
9.9	8.0	5.3	3.9	4.6	2.6	4	0	4	P 3BP	1	BP	GOLDEN BR	+	40.0	SMOOTH
9.3	7.2	4.3	3.3	3.6	2.2	7	0	3	P 2BP	1	BP	GOLDEN BR	++	37.0	SMOOTH
7.7	6.9	4.2	3.4	3.8	2.3	6	0	4	P 3BP	1	BP	GOLDEN BR	+	43.5	SMOOTH
7.8	6.5	4.4	3.5	3.7	2.3	5	0	2	P BP	1	BP	GOLDEN BR	++	52.0	SMOOTH
8.0	6.9	4.4	3.5	3.7	2.4	4	0	3	P 2BP	1	BP	GOLDEN BR	(+)	46.0	SMOOTH
6.9	5.3	3.9	2.8	3.2	1.9	6	0	2	P BP	1	BP	GOLDEN BR	++	45.5	SMOOTH
11.8	9.7	5.9	5.0	5.8	3.1	5.9	0.0	3.9		1.0				43.1	
4.8	3.9	1.6	1.9	2.2	0.9	1.1	0.0	2.3		0.4				4.2	

Elmia species "C"-ELM 164 UF 41461

W/L	ApH/L	ApW/ApH	ApW/ApL	ApL/L	W/2ndL	ApW/W	ApW/L
0.43	0.41	0.56	0.52	0.45	0.55	0.54	0.23
0.43	0.43	0.55	0.46	0.48	0.56	0.54	0.24
0.43	0.41	0.55	0.46	0.48	0.52	0.53	0.23
0.49	0.44	0.59	0.58	0.48	0.61	0.53	0.28
0.47	0.44	0.57	0.51	0.49	0.56	0.54	0.25
0.50	0.40	0.61	0.57	0.43	0.60	0.49	0.25
0.58	0.48	0.61	0.55	0.61	0.73	0.48	0.28
0.51	0.39	0.58	0.56	0.45	0.65	0.51	0.26
0.48	0.41	0.65	0.58	0.45	0.60	0.55	0.26
0.54	0.40	0.67	0.57	0.47	0.66	0.46	0.27
0.52	0.40	0.67	0.61	0.43	0.60	0.51	0.27
0.55	0.44	0.68	0.61	0.46	0.35	0.55	0.30
0.58	0.46	0.66	0.62	0.46	0.66	0.52	0.30
0.55	0.44	0.69	0.65	0.48	0.65	0.55	0.30
0.59	0.44	0.66	0.59	0.48	0.74	0.49	0.29
0.51	0.42	0.63	0.57	0.47	0.60	0.52	0.27
0.05	0.02	0.05	0.05	0.02	0.09	0.02	0.02

Elimia mutabilis-ELR 117, UF 291800

L	2nd L	W	ApH	ApL	ApW	#Wh	Ribs	BWSPC	PosBWC	SWSC	PosSpSC	Color	Banding	Angle	Sculpture
21.0	17.6	10.2	8.8	8.7	5.5	5	13	7	2AP P 4BP	3	AP P BP	GOLDEN BR		46.5	SMOOTH
22.9	19.3	10.3	9.7	10.7	5.4	4	8	4	3AP P	1	BP	GOLDEN BR		42.0	SMOOTH
22.6	20.0	10.8	10.5	9.9	9.0	3	6	1	AP	2	P BP	GOLDEN BR		33.5	SMOOTH
20.5	17.2	10.1	8.7	9.6	6.0	4	6	1	AP	1	BP	GOLDEN BR	-	38.0	SMOOTH
18.5	13.8	8.7	7.2	9.0	4.4	4	11	7	3AP P 3BP	1	BP	GOLDEN BR	++	45.5	SMOOTH
15.9	14.0	7.8	6.9	7.4	3.9	5	11	6	3AP P 2BP	1	P	GOLDEN BR		38.0	SMOOTH
19.9	17.0	9.7	8.6	9.2	5.0	4.2	8.2	4.3		1.5				40.6	
2.7	2.4	1.0	1.3	1.1	0.7	0.7	4.3	2.6		0.8				4.8	

Elimia mutabilis-ELR 117 UF 251609

W/L	ApH/L	ApW/ApH	ApW/ApL	ApL/L	W/2ndL	ApW/W	ApW/L
0.49	0.42	0.62	0.57	0.46	0.56	0.54	0.26
0.45	0.43	0.56	0.50	0.47	0.53	0.52	0.24
0.46	0.46	0.57	0.61	0.43	0.54	0.56	0.27
0.48	0.42	0.57	0.52	0.47	0.59	0.50	0.24
0.53	0.44	0.61	0.55	0.48	0.63	0.51	0.27
0.46	0.42	0.59	0.53	0.47	0.58	0.50	0.25
0.49	0.43	0.59	0.55	0.46	0.57	0.52	0.25
0.02	0.02	0.02	0.04	0.02	0.03	0.02	0.01

Elimia timida ELM 160, UF 286247

L	2nd L	W	ApH	ApL	ApW	#Wh	Ribs	BWSPC	PosBWC	SWSC	PosSpSC	Color	Banding	Angle	Sculpture
12.8	6.3	5.2	4.7	4.9	3.0	8	12	1	1AP	1	1AP	OLIVE GR		42.0	SMOOTH
12.3	8.6	4.8	4.7	4.8	2.8	8	12	1	1AP	1	1AP	OLIVE GR		32.0	SMOOTH
15.0	10.6	6.6	5.8	6.6	3.2	9	16	1	1AP	1	1AP	OLIVE GR		35.0	SMOOTH
13.7	9.7	5.4	5.2	5.3	2.9	8	14	1	1AP	1	1AP	OLIVE GR		57.0	SMOOTH
13.9	10.0	5.5	4.8	5.8	3.8	8	18	0	0	1	1P	OLIVE GR	-	34.0	SMOOTH
12.8	9.1	5.2	4.8	4.7	2.7	8	13	2	1P 1AP	1	1AP	OLIVE GR		33.0	SMOOTH
15.7	10.8	6.8	5.8	6.2	3.3	6	13	2	2AP	2	1AP 1BP	OLIVE GR	-	35.0	SMOOTH
12.8	9.4	4.8	4.8	5.1	2.7	9	15	1	1AP	1	1AP	OLIVE GR	-	38.0	SMOOTH
13.3	9.4	5.1	4.7	4.8	2.6	7	15	1	1AP	1	1AP	OLIVE GR	-	38.0	SMOOTH
13.8	9.7	5.2	4.7	5.3	2.8	8	14	1	1AP	1	1AP	OLIVE GR	-	34.0	SMOOTH
12.2	8.1	4.8	4.8	4.7	2.8	8	16	1	1AP	1	1AP	OLIVE GR	-	38.5	SMOOTH
14.2	10.2	5.4	5.4	5.6	3.2	9	16	1	1AP	1	1AP	OLIVE GR		35.5	SMOOTH
13.7	10.6	6.1	6.0	6.8	3.8	6	11	1	1AP	1	1AP	OLIVE GR		39.5	SMOOTH
12.3	9.0	6.6	5.2	4.2	2.7	8	13	1	1AP	2	1AP 1P	OLIVE GR		39.8	SMOOTH
13.8	9.8	5.8	5.4	5.5	3.1	8	13	0	0	1	1AP	OLIVE GR	-	37.0	SMOOTH
12.3	8.9	5.2	4.8	4.8	2.8	10	15	1	1AP	2	1AP 1BP	OLIVE GR	-	40.0	SMOOTH
17.0	11.3	8.3	6.0	6.2	3.4	8	17	1	1BP	1	1AP	OLIVE GR		29.5	SMOOTH
12.8	9.1	5.1	4.5	4.7	2.7	8	12	1	1BP	1	1AP	OLIVE GR		37.0	SMOOTH
12.6	9.4	5.7	4.8	4.8	2.9	8	13	1	1AP	2	1BP 1AP	OLIVE GR	-	32.0	SMOOTH
14.5	10.8	5.8	5.3	5.8	5.6	7	12	1	1BP	1	1AP	OLIVE GR	-	35.5	SMOOTH
12.5	8.2	5.1	4.4	4.7	2.6	8	12	1	1BP	2	1AP 1BP	OLIVE GR	-	37.0	SMOOTH
12.4	8.8	5.1	4.8	4.7	2.7	8	12	1	1AP	2	1P 1AP	OLIVE GR		36.0	SMOOTH
13.5	9.7	5.5	5.0	5.2	3.0	8.2	13.7	1.0		1.3				36.1	
1.2	0.7	0.5	0.5	0.6	0.3	0.7	1.7	0.4		0.4				2.8	
13.0	8.5	5.2	?	?	?	8	13	1	1AP	1	1AP	OLIVE GR	-	37.0	SMOOTH
18.7	11.9	6.4	6.5	6.4	3.6	8	?	0	0	1	1AP	OLIVE GR		37.0	SMOOTH
13.2	9.2	5.3	4.8	4.8	3.0	9	14	1	1AP	2	1P 1AP	OLIVE GR		33.0	SMOOTH
13.8	9.7	5.5	5.1	5.3	3.0	8.2	13.4	1.0		1.3				36.6	
1.3	0.8	0.5	1.3	0.8	0.5	0.8	1.2	0.4		0.4				2.8	

Elimia limida, ELM 160, UF 286247

W/L	ApH/L	ApW/ApH	ApW/ApL	ApL/L	W/2ndL	ApW/W	ApW/L
0.41	0.37	0.64	0.61	0.38	0.56	0.56	0.23
0.40	0.38	0.60	0.58	0.39	0.55	0.57	0.23
0.40	0.39	0.55	0.53	0.40	0.58	0.53	0.21
0.38	0.38	0.56	0.55	0.39	0.56	0.54	0.21
0.40	0.38	0.60	0.70	0.40	0.55	0.71	0.28
0.41	0.36	0.59	0.57	0.37	0.57	0.52	0.21
0.44	0.38	0.56	0.53	0.36	0.63	0.48	0.21
0.38	0.37	0.56	0.53	0.40	0.52	0.58	0.21
0.38	0.35	0.60	0.57	0.37	0.54	0.55	0.21
0.37	0.34	0.60	0.53	0.38	0.51	0.54	0.20
0.38	0.38	0.63	0.62	0.39	0.53	0.60	0.24
0.38	0.38	0.59	0.67	0.38	0.53	0.56	0.23
0.45	0.44	0.63	0.58	0.48	0.61	0.62	0.28
0.48	0.42	0.52	0.64	0.54	0.67	0.45	0.22
0.43	0.40	0.57	0.56	0.40	0.56	0.53	0.23
0.42	0.37	0.63	0.60	0.39	0.58	0.56	0.24
0.37	0.35	0.57	0.55	0.38	0.56	0.54	0.20
0.40	0.36	0.60	0.57	0.37	0.56	0.53	0.21
0.44	0.37	0.60	0.59	0.38	0.61	0.51	0.22
0.40	0.37	0.57	0.54	0.39	0.54	0.52	0.21
0.41	0.35	0.66	0.62	0.38	0.55	0.57	0.23
0.41	0.37	0.59	0.57	0.38	0.57	0.53	0.22
0.41	0.37	0.60	0.58	0.38	0.57	0.55	0.22
0.03	0.03	0.05	0.04	0.03	0.04	0.05	0.02
0.40					0.55		
0.38					0.54		
0.40					0.58		
0.41					0.57		
0.03					0.04		

APPENDIX C
MORPHOLOGICAL ANALYSES OF THE TYPES RELEVANT TO THE SOUTHEASTERN *ELIMIA*

Appendix C contains the morphological datasets of the type specimens. The type datasets are arranged alphabetically as they are listed below. The variable L, 2nd L, W, ApH, ApL, ApW are measured in millimeters. The variable Angle is measured in degrees. The quantity was noted for the number of whorls (#WH), ribs, spiral chords on the body whorl (BW) and penultimate whorl of the spire (SpW). The variables PBW (Position on the Body Whorl) and PSPW (Position on the Penultimate Whorl) indicate the position of the spiral chords relative to the periphery of the whorl.

Melania curvicostata Reeve, 1861, Types BMNH 1994058.

Melania densicostata Reeve, 1861 Types BMNH 1994057

Goniobasis doolyensis Lea 1862 Lectotype USNM 119121 Paralectotypes USNM 873106

Goniobasis elliotti Lea 1862 Lectotype USNM 119122, Paralectotypes USNM 873113

Goniobasis etowahensis Lea 1862 Lectotype USNM 121479

Goniobasis gesneri Lea 1868 Lectotype USNM 119134

Goniobasis inclinans Lea 1862 Lectotype USNM 118743 Paralectotypes USNM 873102

Goniobasis induta Lea, 1862 Lectotype USNM 11974 Paralectotypes USNM 873111

Goniobasis inosculata Lea 1862 Lectotype USNM 119177 Paralectotypes USNM 873115

Melania modesta Lea 1845 Lectotype USNM 119189

Goniobasis mutabilis Lea 1862 Holotype USNM 118443 Paratypes USNM 118493

Goniobasis mutabilis timidus Goodrich 1942 Holotype UMMZ 490211 Paratypes UMMZ 49211

Goniobasis ucheensis Lea 1862, Lectotype USNM 1199258 Paralectotypes USNM 873110

Goniobasis viennaensis Lea 1862 Lectotype USNM 118743 Paralectotypes USNM 873110

TYPE SPECIMENS	L	2nd L	W	ApH	ApL	Ap	#Wh	R	BW	PBW	SW	PSpC	A	W/L	W/2nd	AW/AH	AW/AL
Melania curvicostata Reeve 1861 lectotype BMNH 1994058	17.4	13.6	7.8	8.7	7.6	4.7	4	14	0	0	0	0	31.0	0.45	0.57	0.70	0.60
paralectotypes (N=2)	17.0	12.5	7.5	7.0	6.5	4.5	5	0	0	0	0	0	27.5	0.44	0.60	0.64	0.53
	16.6	14.1	7.6	7.0	6.5	4.6	5	0	0	0	2	P BP	26.0	0.42	0.55	0.66	0.54
MEAN	17.6	13.4	7.7	6.9	6.3	4.6	4.7	5	0		0.67		28.2	0.44	0.58	0.67	0.56
STANDARD DEVIATION	0.6	0.7	0.6	0.1	0.3	0.1	0.6	6.6	0		0.94		2.1	0.01	0.02	0.02	0.03
MAXIMUM	18.5	14.1	7.8	7	6.5	4.7	5	14	0		2		31.0	0.45	0.60	0.70	0.60
MINIMUM	17.0	12.5	7.5	6.7	7.6	4.6	4.0	0.0	0		0		26.0	0.42	0.55	0.64	0.53
Melania densicostata Reeve 1861 lectotype BMNH 1994057	16.0	12.7	6.5	5.5	6.8	4.2	5	17	0	0	0	0	30.0	0.41	0.51	0.76	0.61
paralectotypes (N=2)	16.2	10.9	6.3	5.4	6.2	3.9	5	15	0	0	0	0	28.0	0.41	0.56	0.70	0.61
	15.4	11.4	6.6	5.7	6.6	4.0	5	16	0	0	0	0	32.0	0.43	0.56	0.70	0.45
MEAN	15.5	11.6	6.5	5.5	7.3	4.0	5.0	16.0	0		0		30.0	0.42	0.56	0.72	0.56
STANDARD DEVIATION	0.3	0.6	0.1	0.1	1.1	0.2	0.0	0.6	0		0		1.6	0.01	0.03	0.03	0.07
MAXIMUM	16.0	12.7	6.6	5.7	6.8	4.2	5.0	17.0	0		0		32.0	0.43	0.56	0.76	0.61
MINIMUM	15.2	10.9	6.3	5.4	6.2	3.9	5.0	15.0	0		0		28.0	0.41	0.51	0.70	0.45
Goniobasis okolyensis Lea 1862 lectotype USNM 118121	22.0	15.6	8.3	6.6	7.3	3.9	8	12	0	0	0	0	28.5	0.68	0.55	0.47	0.53
paralectotypes USNM 873108 (N=33)	20.6	14.6	8.4	7.0	7.7	4.2	5	17	2	P,AP	0	0	22.0	0.40	0.57	0.50	0.55
	18.8	13.6	7.8	NA	NA	NA	5	NA	0	0	0	0	32.0	0.41	0.58	NA	NA
	17.4	13.6	7.8	NA	NA	NA	6	15	0	0	0	0	30.5	0.45	0.57	NA	NA
	19.4	13.6	7.7	6.0	6.7	3.9	6	14	0	0	0	0	48.0	0.40	0.57	0.51	0.56
	16.0	14.6	7.6	6.7	7.6	4.1	12	12	0	0	1	BP	28.0	0.40	0.51	0.54	0.54

TYPE SPECIMENS	L	2nd L	W	ApH	ApL	Ap	#Wh	R	SW	PBW	SW	PSpC	A	W/L	W/2nd	AW/AH	AW/AL
	21.3	14.7	8.0	6.7	7.6	4.0	7	11	0	0	0	0	46.5	0.38	0.54	0.50	0.53
	16.6	11.7	6.4	NA	NA	NA	7	15	0	0	0	0	36.0	0.38	0.55	NA	NA
	18.6	14.2	8.4	6.6	7.2	4.3	6	17	0	0	0	0	29.5	0.45	0.59	0.51	0.60
	17.4	11.6	6.7	5.9	6.6	3.7	7	15	2	P BP	0	0	25.5	0.38	0.57	0.55	0.56
	17.6	13.0	7.0	NA	NA	NA	6	14	0	0	0	0	27.0	0.38	0.54	NA	NA
	15.5	11.0	6.2	4.7	5.2	2.9	6	16	0	0	0	0	29.0	0.40	0.59	0.47	0.56
	17.0	12.7	6.6	5.0	6.6	3.8	8	15	3	P 2BP	0	0	32.0	0.38	0.54	0.52	0.55
	16.8	11.6	6.4	5.6	6.3	3.2	6	19	3	P,AP BP	0	0	30.0	0.38	0.55	0.48	0.51
	15.0	10.3	6.0	4.9	5.4	3.1	7	16	2	BP P	0	0	38.5	0.40	0.58	0.52	0.57
	16.9	12.4	7.1	5.6	6.6	3.6	4	14	2	P,AP	0	0	25.5	0.42	0.57	0.54	0.56
	20.1	13.6	8.1	NA	NA	NA	6	13	0	0	0	0	33.0	0.40	0.59	NA	NA
	16.3	11.6	6.8	5.6	6.3	3.5	6	14	0	0	0	0	35.0	0.42	0.59	0.51	0.56
	18.0	14.1	7.2	NA	NA	NA	6	14	0	0	0	0	35.0	0.40	0.51	NA	NA
	18.4	12.6	6.7	6.0	6.6	3.1	7	14	0	0	0	0	27.0	0.36	0.53	0.52	0.51
	16.7	12.2	7.0	NA	NA	NA	5	13	0	0	0	0	34.0	0.42	0.57	NA	NA
	17.5	12.1	7.2	NA	NA	NA	6	15	0	0	0	0	30.0	0.41	0.60	NA	NA
	18.6	13.2	7.1	6.5	6.6	3.5	8	12	0	0	0	0	34.0	0.38	0.54	0.48	0.53
	16.2	12.1	7.4	NA	NA	NA	5	16	0	0	0	0	29.5	0.46	0.61	NA	NA
	19.2	13.1	7.1	6.2	7.0	3.8	7	16	0	0	0	0	32.0	0.37	0.54	0.54	0.54
	13.6	9.8	5.6	NA	NA	NA	6	16	2	AP P	0	0	37.5	0.41	0.57	NA	NA
	11.3	8.0	4.8	NA	NA	NA	6	16	2	AP P	0	0	35.0	0.42	0.60	NA	NA
	11.5	6.0	5.0	NA	NA	NA	6	12	3	AP P	0	0	27.5	0.43	0.83	NA	NA
	11.6	8.1	4.8	NA	NA	NA	6	17	1	P	0	0	32.0	0.42	0.60	NA	NA
	12.7	9.1	5.4	NA	NA	NA	6	15	2	P,AP	0	0	26.5	0.43	0.59	NA	NA
	12.9	9.3	5.1	NA	NA	NA	6	13	2	AP P	0	0	37.5	0.40	0.55	NA	NA
	10.6	8.7	4.5	NA	NA	NA	8	16	2	AP P	0	0	37.5	0.42	0.52	NA	NA
	8.5	5.7	4.0	NA	NA	NA	7	11	2	AP P	0	0	31.5	0.47	0.70	NA	NA
	7.8	5.5	3.7	3.2	3.4	1.8	6	10	4	P 3AP	0	0	50.0	0.48	0.67	0.49	0.53
MEAN	16.3	11.7	6.8	5.6	6.5	3.5	6.7	14.0	1.0		0.03		32.7	0.42	0.57	0.51	0.54
STANDARD DEVIATION	3.6	2.5	1.3	0.9	1.0	0.6	1.5	3.1	1.2		0.2		6.0	0.05	0.04	0.02	0.02
MAXIMUM	22.0	16.0	8.4	7.0	7.7	4.3	12.0	19	4		1.0		50.0	0.48	0.70	0.55	0.60
MINIMUM	7.8	5.5	3.7	3.2	3.4	1.8	4.0	6.0	0.0		0.0		22.0	0.36	0.51	0.47	0.51
Goniobasis elliotti Lea 1862	21.4	17.4	10.4	6.7	9.5	5.6	0	6	4	2AP P BP	0	0	37.5	0.48	0.60	0.54	0.58

TYPE SPECIMENS lectotype: USNM 116122	L	2nd L	W	ApH	ApL	Ap	#Wh	R	BW	PBW	SW	PSpC	A	W/L	W/2nd	AW/AH	AW/AL
paralectotypes: USNM 873113 (N=10)	27.3	16.6	10.3	9.6	10.6	6.4	0	6	2	BP	3	P,2AP	31.5	0.38	0.63	0.52	0.56
	22.1	18.3	10.6	5.6	6.7	6.0	0	5	2	BP	2	BP,P	42.0	0.48	0.58	0.75	0.92
	22.5	19.5	11.3	9.9	11.3	5.8	0	4	2	P,BP	1	AP	42.5	0.50	0.58	0.51	0.51
	20.9	17.1	9.8	8.3	8.8	4.9	0	5	2	P,BP	3	P,2AP	38.0	0.47	0.57	0.59	0.56
	20.2	17.6	10.0	8.5	9.6	5.4	0	4	0	0	1	BP	46.5	0.50	0.57	0.54	0.56
	20.0	12.9	8.0	8.0	9.5	4.7	0	6	2	P,AP	0	0	43.0	0.40	0.62	0.58	0.49
	18.3	16.7	9.7	NA	NA	NA	0	4	1	AP	0	0	38.5	0.53	0.58	NA	NA
	18.6	16.0	10.5	NA	NA	NA	0	4	0	0	1	BP	41.5	0.56	0.66	NA	NA
	15.6	14.7	7.8	7.0	7.8	4.1	0	6	2	P,AP	1	BP	29.0	0.41	0.53	0.53	0.54
	10.0	8.8	5.1	4.5	4.7	2.7	0	3	2	P,AP	3	AP,P,BP	38.0	0.51	0.58	0.53	0.57
MEAN	20.1	16.2	9.4	7.6	8.9	6.2	0.0	4.6	1.7		1.4		38.9	0.47	0.56	0.56	0.58
STANDARD DEVIATION	3.9	14.2	6.3	1.9	1.9	1.9	0.0	4.0	1.3		1.2		35.9	0.43	0.53	0.03	0.08
MAXIMUM	27.3	18.9	11.3	9.9	11.3	6.0	0.0	6.0	4.0		3.0		46.5	0.56	0.66	0.75	0.92
MINIMUM	10.0	8.8	5.1	9.9	11.3	6.0	0.0	3.0	0.0		0.0		29.0	0.38	0.53	0.75	0.92
Goniobasis etowahensis Lea 1862 lectotype USNM 121470	18.0	14.3	7.0	6.6	7.0	3.6	0	0	3	P,2BP	3	AP,2BP	42.0	0.39	0.49	0.54	0.54
Goniobasis gesneri Lea 1868 lectotype USNM 119134	16.0	13.2	9.2	6.6	9.7	4.2	0	2	7	P,5BP,AP	3	BP,P,AP	50.0	0.61	0.67	0.48	0.43
Goniobasis inclinans Lea 1862 lectotype USNM 116743	17.6	12.0	6.9	8.4	8.7	3.7	0	10	6	P,4BP,2AP	4	BP,P,2AP	24.6	0.39	0.58	0.84	0.65
paralectotypes. USNM 673102 (N=24)	15.1	10.4	5.4	6.0	6.7	3.8	0	14	0	P,2AP,5BP	1	AP	37.5	0.36	0.52	0.70	0.57
	16.9	13.2	7.1	7.2	7.6	4.4	5	15	6	P,3AP,4BP	5	P,2AP,2BP	56.5	0.42	0.54	0.62	0.58
	13.0	9.8	5.3	5.2	5.6	3.6	6	15	0	P,2AP,2BP	4	2AP,2BP	32.0	0.41	0.54	0.68	0.63
	16.2	14.2	7.4	NA	NA	NA	4	19	0	2AP,5BP	7	P,AP,5BP	27.0	0.41	0.52	NA	NA
	15.9	12.4	7.5	7.2	7.7	4.7	5	17	6	2AP,P,2BP	6	P,2AP,5BP	29.5	0.47	0.60	0.63	0.61
	11.6	8.9	5.4	NA	NA	NA	6	14	0	0	3	P,AP,BP	22.5	0.46	0.61	NA	NA

TYPE SPECIMENS	L	2nd L	W	ApH	ApL	Ap	#Wh	R	BW	PBW	SW	PSpC	A	W/L	W/2nd	AW/AH	AW/AL
	13.6	10.7	6.1	6.5	6.7	4.3	5	13	10	P,4AP,5BP	3	2AP,P	36.0	0.48	0.57	0.76	0.64
	15.4	11.1	8.3	6.6	7.0	4.7	5	16	5	P,2AP,2BP	6	P,5BP	31.5	0.41	0.57	0.75	0.67
	15.7	11.6	6.8	6.6	7.3	4.7	5	13	8	P,2AP,5BP	4	2AP,P,BP	38.5	0.43	0.56	0.69	0.64
	13.3	10.6	6.9	6.5	6.8	4.1	5	13	3	2AP	4	2AP,2BP	55.0	0.44	0.56	0.66	0.62
	12.7	9.2	6.0	5.3	5.7	3.6	6	14	6	3AP,P,2BP	4	2AP,2BP	34.0	0.39	0.54	0.72	0.63
	13.7	9.7	5.1	5.0	6.3	3.5	6	8	2	BP,AP	1	BP	34.5	0.37	0.53	0.69	0.66
	14.2	9.6	5.9	NA	NA	NA	7	9	3	2AP,P	3	AP,P,BP	27.5	0.36	0.57	NA	NA
	14.2	10.2	5.6	NA	NA	NA	6	12	3	P,2AP	4	2AP,2BP	34.5	0.39	0.55	NA	NA
	14.6	10.9	5.6	NA	NA	NA	6	15	1	AP	0	0	23.0	0.38	0.54	NA	NA
	12.7	9.3	1.2	5.5	5.6	3.6	7	13	5	2AP,P,2BP	5	P,2AP,2BP	26.0	0.09	0.13	NA	0.68
	12.9	10.1	5.2	NA	NA	NA	6	14	5	4AP,P	3	P,AP,BP	35.5	0.40	0.51	NA	NA
	13.4	9.8	6.1	NA	NA	NA	6	13	5	2AP,P,2BP	5	2AP,P,2BP	33.5	0.38	0.52	NA	NA
	12.0	9.6	5.0	NA	NA	NA	6	15	8	4AP,P,3BP	5	2AP,2BP,P	37.5	0.42	0.56	NA	NA
	11.3	8.2	5.4	5.0	5.5	3.5	6	12	7	P,2AP,4BP	4	2AP,2BP	38.5	0.48	0.66	0.65	0.64
	15.5	11.5	6.6	6.7	7.3	4.3	6	12	6	3AP,P,4BP	4	2AP,2BP	30.0	0.43	0.57	0.65	0.59
*	11.4	8.1	4.6	NA	NA	NA	6	13	2	P,AP	0	0	33.0	0.42	0.58	NA	NA
	13.2	9.3	4.7	NA	NA	NA	7	16	5	P,2AP,2BP	0	0	30.5	0.38	0.51	NA	NA
	9.6	7.3	4.4	NA	NA	NA	7	12	9	P,3AP,2BP	3	P,2AP	20.0	0.44	0.60	NA	NA
MEAN	13.9	10.3	5.6	6.1	6.5	4.0	6.1	13.5	5.4		3.6		32.3	0.40	0.54	0.62	0.62
STANDARD DEVIATION	2.0	1.6	1.2	0.7	0.6	0.5	1.0	2.4	2.8		2.0		7.0	0.07	0.08	0.18	0.04
MAXIMUM	18.2	14.2	7.5	7.2	7.7	4.7	8	18	10		6		55.0	0.48	0.66	0.75	0.68
MINIMUM	9.6	7.3	1.2	5.0	5.6	3.5	4.0	6.0	0.0		0.0		20.0	0.09	0.13	0.00	0.56
Goniobasis induta Lea 1862 lectotype USNM 11974	18.7	13.4	7.4	6.5	7.1	4.6	6	16	2	2AP	2	AP	20.0	0.40	0.55	0.66	0.69
paralectotypes, USNM 873111 (N=41)	16.1	14.8	7.7	6.8	6.0	3.7	6	14	1	AP	0	0	29.0	0.43	0.52	0.48	0.62
	15.5	11.2	6.4	5.6	6.3	3.6	7	14	1	AP	1	AP	48.5	0.41	0.57	0.56	0.57
	17.4	14.0	7.3	6.2	6.5	3.6	5	17	0	0	2	2AP	30.0	0.42	0.52	0.53	0.60
	16.0	13.0	6.5	NA	NA	NA	6	14	1	AP	2	AP	48.5	0.41	0.50	NA	NA
	15.0	11.0	5.3	NA	NA	NA	6	14	1	AP	2	2AP	32.5	0.35	0.48	NA	NA
	19.5	12.2	6.7	NA	NA	NA	6	13	1	AP	1	AP	19.0	0.41	0.55	NA	NA
	15.9	10.6	6.2	5.2	5.7	3.3	7	14	2	2AP	2	2AP	34.6	0.39	0.58	0.53	0.56
	16.1	12.0	6.6	5.6	6.4	3.7	5	13	2	2AP	1	AP	30.0	0.41	0.55	0.56	0.58

TYPE SPECIMENS

L	2nd L	W	ApH	ApL	Ap	#Wh	R	SW	PBW	SW	PSpC	A	W/L	W/2nd	AW/AH	AW/AL
14.4	10.0	4.4	4.8	6.3	3.3	8	10	1	AP	1	BP	38.0	0.31	0.44	0.75	0.62
14.7	10.8	5.8	NA	NA	NA	8	14	1	AP	1	AP	31.0	0.39	0.54	NA	NA
14.2	10.4	5.5	NA	NA	NA	6	13	2	2AP	1	AP	29.0	0.39	0.53	NA	NA
13.9	10.2	5.8	4.7	5.7	2.9	7	14	1	AP	1	AP	38.0	0.42	0.56	0.49	0.51
13.6	9.7	5.2	4.8	5.3	3.3	8	12	2	2AP	2	AP	37.5	0.38	0.54	0.63	0.62
14.3	9.8	5.3	4.8	5.3	2.8	8	13	1	AP	1	AP	33.5	0.37	0.54	0.53	0.53
14.0	10.0	5.1	4.4	4.9	2.8	7	14	1	AP	1	AP	31.5	0.36	0.51	0.55	0.57
14.2	9.9	5.3	NA	NA	NA	6	12	4	2AP P BP	1	AP	32.0	0.37	0.54	NA	NA
13.7	8.6	5.7	NA	NA	NA	9	12	1	AP	1	AP	30.0	0.42	0.66	NA	NA
12.9	9.5	4.9	4.6	5.4	3.1	8	12	1	AP	1	AP	35.5	0.38	0.52	0.63	0.57
13.5	9.9	5.5	NA	NA	NA	7	16	3	2AP P	1	AP	33.5	0.41	0.56	NA	NA
12.8	9.3	5.0	NA	NA	NA	8	14	1	AP	2	3AP	34.0	0.39	0.54	NA	NA
11.8	8.3	4.4	4.1	4.4	2.5	8	14	4	3AP P	1	AP	33.0	0.37	0.53	0.57	0.57
11.5	8.5	4.7	3.7	4.1	2.5	8	14	4	P 3AP	2	2AP	35.0	0.41	0.55	0.53	0.61
13.2	9.5	5.0	3.8	4.2	2.8	8	12	1	AP	1	AP	38.5	0.38	0.53	0.52	0.62
12.1	9.0	5.1	4.2	4.5	2.7	9	12	8	P 4AP 3BP	1	AP	34.0	0.42	0.57	0.53	0.56
11.9	8.9	4.8	3.5	4.5	2.8	8	12	6	P 3AP,2BP	2	2AP	39.5	0.40	0.54	0.58	0.52
11.6	8.9	5.1	NA	NA	NA	7	10	3	2AP P	1	AP	37.0	0.44	0.57	NA	NA
11.8	8.3	4.8	NA	NA	NA	7	13	3	2AP P	1	AP	34.0	0.41	0.58	NA	NA
13.0	8.2	4.7	NA	NA	NA	8	11	1	AP	1	AP	36.0	0.36	0.57	NA	NA
13.8	9.8	5.2	NA	NA	NA	9	16	1	AP	1	AP	31.5	0.38	0.53	NA	NA
11.4	9.0	4.8	NA	NA	NA	7	13	3	P,2AP	2	2AP	34.0	0.42	0.53	NA	NA
10.4	7.9	4.4	NA	NA	NA	5	13	2	P,AP	1	AP	31.0	0.42	0.56	NA	NA
13.0	9.6	5.6	NA	NA	NA	7	11	1	AP	1	AP	33.5	0.43	0.58	NA	NA
13.0	9.5	5.1	NA	NA	NA	8	11	8	2AP P	2	2AP	39.5	0.39	0.54	NA	NA
8.0	5.7	4.5	NA	NA	NA	7	12	2	3AP P	2	AP BP	38.5	0.56	0.79	NA	NA
8.0	5.6	3.8	3.8	3.1	2.6	8	13	2	P,AP	1	AP	38.5	0.48	0.68	0.68	0.84
10.1	6.6	4.4	NA	NA	NA	8	14	1	P	0	0	38.5	0.44	0.67	NA	NA
9.7	6.7	3.9	3.4	3.7	2.2	8	12	1	AP	1	AP	41.5	0.40	0.58	0.58	0.59
10.6	7.4	4.4	NA	NA	NA	7	13	9	P 3AP 3BP	2	2AP	38.5	0.42	0.59	NA	NA
9.9	7.8	3.9	NA	NA	NA	7	10	3	P,2AP	1	AP	32.5	0.39	0.50	NA	NA
11.6	6.2	4.3	3.8	4.2	2.5	8	14	3	P,2AP	1	AP	28.0	0.37	0.62	0.56	0.60
12.7	8.2	5.1	NA	NA	NA	8	12	4	P 3AP	3	P,AP BP	45.0	0.40	0.62	NA	NA

	L	2nd L	W	ApH	ApL	Ap	#Wh	R	SW	PBW	SW	PSpC	A	W/L	W/2nd	AW/AH	AW/AL
MEAN	13.2	8.8	5.3	4.5	4.8	2.8	7.8	13.0	2.3		1.3		38.3	0.40	0.56	0.55	0.56
STANDARD DEVIATION	2.4	2.0	0.8	3.1	3.4	2.0	0.9	1.6	1.9		0.8		5.4	0.04	0.06	0.38	0.38
MAXIMUM	16.7	14.8	7.7	6.6	7.1	4.8	9.0	17.0	9.0		3.0		46.0	0.56	0.79	0.75	0.84

TYPE SPECIMENS	L	2nd L	W	ApH	ApL	Ap	#Wh	R	θW	PBW	SW	PSpC	A	W/L	W/2nd	AW/AH	AW/AL
MINIMUM	6.6	5.6	3.6	3.4	3.1	2.2	5.0	10.0	0.0		0.0		19.0	0.31	0.44	0.56	0.51
Goniobasis inosculata Lea 1862 lectotype USNM 119177	16.7	13.0	7.0	6.6	7.0	3.8	6	0	3	P,2BP	3	AP,2BP	38.8	0.42	0.54	0.54	0.54
lectoparatypes, USNM 873115 (N=7)	14.0	11.5	6.3	5.7	6.1	3.0	5	0	0	0	0	0	37.0	0.45	0.55	0.56	0.48
	12.8	9.8	5.7	5.8	5.2	3.1	6	0	0	0	0	0	35.5	0.56	0.68	0.54	0.60
	16.0	13.5	7.2	6.3	6.7	3.8	5	0	1	AP	0	0	44.5	0.40	0.53	0.53	0.57
	15.3	12.0	6.2	5.9	6.3	3.5	5	0	1	BP	1	AP	34.5	0.41	0.52	0.56	0.56
	16.1	12.2	6.6	5.6	6.4	3.6	6	0	3	3AP	2	P,AP	34.0	0.41	0.54	0.53	0.55
	13.3	10.0	5.7	6.2	5.8	3.1	4	0	0	0	1	BP	32.0	0.45	0.56	0.54	0.55
	12.4	8.2	4.9	4.5	5.0	2.9	5	0	3	P,2AP	3	2BP,AP	32.5	0.40	0.53	0.56	0.58
MEAN	14.6	12.2	6.2	5.7	6.0	3.3	5.4	0.0	1.0		1.3		36.1	0.42	0.52	0.54	0.55
STANDARD DEVIATION	1.6	2.0	0.7	0.6	0.7	0.3	0.7	0.0	1.2		1.2		3.6	0.02	0.06	0.03	0.03
MAXIMUM	16.0	16.0	7.2	6.6	7.0	3.8	6.0	0.0	3.0		3.0		44.5	0.45	0.56	0.56	0.60
MINIMUM	12.4	8.2	4.9	4.5	5.0	2.9	4.0	0.0	0.0		0.0		32.0	0.40	0.56	0.48	0.48
Melania modesta Lea 1845 holotype USNM 118189	15.0	13.1	7.1	6.6	7.4	3.7	4	0	2	P,BP	0	0	47.5	0.47	0.54	0.52	0.50
Goniobasis mutabilis Lea 1862 holotype, USNM 118443	18.3	12.5	7.0	6.0	6.8	4.6	5	0	8	P,4BP,4AP	2	2BP	54.5	0.46	0.56	0.66	0.52
paratypes USNM 118493 (N=21)	18.6	15.9	6.5	7.6	8.5	4.9	4	0	6	P,6BP,AP	2	BP	34.0	0.45	0.53	0.56	0.54
	15.3	12.6	8.0	6.6	7.4	4.3	4	0	6	P,7BP	1	BP	43.5	0.52	0.63	0.54	0.56
	16.7	13.3	7.7	6.6	7.5	4.3	6	0	6	P,AP,3BP	1	BP	56.0	0.46	0.54	0.56	0.57
	14.2	12.1	7.3	6.0	6.6	3.9	5	0	4	P,2AP,2BP	2	BP	56.5	0.61	0.60	0.53	0.56
	14.6	12.3	6.6	NA	NA	NA	6	0	6	P,AP,4BP	1	BP	44.5	0.48	0.56	NA	NA
	14.6	12.6	7.0	5.6	6.3	3.6	5	0	7	P,AP,5BP	2	BP	38.5	0.46	0.56	0.51	0.57
	15.6	13.3	7.6	NA	NA	NA	6	14	2	P,AP	2	AP,BP	46.0	0.50	0.56	NA	NA
	14.1	12.6	7.6	6.6	7.5	4.2	3	0	3	P,2BP	2	P,BP	56.0	0.56	0.52	0.53	0.56

TYPE SPECIMENS	L	2nd L	W	ApH	ApL	Ap	#Wh	R	BW	PBW	SW	PSpC	A	W/L	W/2nd	AW/AH	AW/AL
	14.2	12.0	6.7	NA	NA	NA	5	0	7	2AP P 4BP	2	2BP	41.8	0.47	0.48	NA	NA
	15.1	12.8	7.2	6.8	7.2	3.5	5	0	5	P 2AP 2BP	1	BP	48.5	0.48	0.48	0.49	0.49
	13.5	11.3	6.8	5.8	6.4	3.3	5	0	7	P,AP 5BP	1	BP	37.5	0.50	0.60	0.49	0.52
	11.7	8.7	5.9	4.9	5.6	3.1	6	0	4	P 3BP	2	BP,AP	40.5	0.50	0.60	0.53	0.55
	13.8	12.0	6.6	6.3	6.6	3.6	4	0	2	AP,P	1	BP	40.8	0.50	0.57	0.53	0.55
	14.0	11.8	6.8	6.2	6.6	3.4	5	0	6	P SP 4BP	1	BP	48.5	0.49	0.48	0.49	0.52
	14.4	12.2	6.9	6.0	6.5	3.5	6	0	6	P 2AP 3BP	2	BP	54.5	0.48	0.57	0.51	0.54
	14.0	11.9	7.0	6.2	6.6	3.7	6	0	2	P,AP	1	BP	35.0	0.50	0.49	0.53	0.48
	14.5	11.9	7.0	6.3	6.7	3.7	7	0	6	P 2AP 3BP	1	BP	35.0	0.48	0.59	0.53	0.55
	13.1	11.0	6.6	NA	NA	NA	6	0	7	P 2AP 4BP	1	BP	45.0	0.50	0.60	NA	NA
	9.9	8.2	5.2	3.2	4.5	2.8	5	0	6	P 2AP 3BP	2	BP P	42.5	0.48	0.63	0.54	0.52
	10.3	8.7	5.6	NA	NA	NA	4	0	4	P AP 2BP	3	AP 2BP	61.0	0.54	0.64	NA	NA
	9.7	8.8	4.9	3.8	4.8	2.8	6	0	3	P BP,AP	1	BP	57.0	0.51	0.48	0.53	0.57
MEAN	13.2	12.8	7.4	6.1	6.7	3.7	4.8	1.2	5.8		1.8		41.1	0.49	0.48	0.53	0.55
STANDARD DEVIATION	1.4	1.1	0.5	1.2	1.1	0.6	0.7	3.9	2.1		0.5		4.4	0.03	0.03	0.04	0.03
MAXIMUM	15.6	16.9	8.5	6.0	6.9	4.9	6.0	14.0	9.0		2.0		48.0	0.48	0.63	0.66	0.62
MINIMUM	13.5	11.3	6.7	3.2	4.5	2.8	3.0	0.0	2.0		1.0		34.0	0.45	0.53	0.49	0.49
Goniobasis mutabilis	16.9	14.0	7.8	NA	NA	3.8	4.9	0	0	0	0.0	0.0	21.0	0.41	0.48	NA	NA
lenidus	16.5	11.0	6.0	5.5	5.7	3.2	6.0	0	0	0	0.0	0.0	24.0	0.38	0.55	NA	NA
Goodrich 1942																	
holotype UMMZ 18443																	
paratypes. UMMZ 49211	15.5	12.0	6.2	5.6	6.1	3.5	5	0	0	0	0	0	21.0	0.40	0.52	0.48	0.57
(N=24)	15.9	12.2	6.3	6.0	6.0	3.4	5	0	0	0	0	0	19.0	0.40	0.52	0.54	0.57
	16.7	12.0	6.3	5.9	5.8	3.1	5	0	0	0	0	0	19.0	0.38	0.53	0.49	0.53
	17.1	12.3	6.5	5.7	5.8	3.3	6	0	0	0	0	0	19.0	0.38	0.53	0.51	0.57
	15.4	11.9	6.3	5.9	5.9	3.4	5	0	0	0	0	0	21.0	0.41	0.53	0.54	0.49
	15.8	11.0	5.7	5.3	5.4	2.9	7	0	0	0	0	0	24.0	0.36	0.52	0.51	0.54
	16.6	11.9	6.3	5.6	5.7	3.4	6	0	0	0	0	0	19.0	0.38	0.53	0.54	0.60
	17.3	12.7	7.0	6.0	6.1	3.9	6	0	0	0	0	0	21.0	0.40	0.55	0.49	0.54
	18.3	14.7	7.5	6.6	6.7	3.9	6	0	0	0	0	0	24.0	0.41	0.51	0.52	0.49
	18.7	13.3	6.6	6.2	6.4	3.4	6	0	0	0	0	0	22.0	0.35	0.50	0.52	0.53
	15.4	12.2	6.6	5.9	5.9	3.3	5	0	3	P 2BP	0	0	18.0	0.43	0.54	0.50	0.49
	17.8	12.4	5.9	5.5	6.0	3.3	6	0	0	0	0	0	18.0	0.33	0.48	0.48	0.55

TYPE SPECIMENS	L	2nd L	W	ApH	ApL	Ap	#Wh	R	BW	PBW	SW	PSpC	A	W/L	W/2nd	AW/AH	AW/AL
	15.6	11.7	6.2	5.6	6.0	3.2	5	0	0	0	0	0	21.0	0.46	0.53	0.52	0.53
	14.0	10.4	5.1	4.7	5.1	3.1	6	0	1	P	0	0	20.0	0.36	0.48	0.61	0.61
	14.2	10.0	6.6	4.6	5.2	2.6	7	0	0	0	0	0	24.0	0.38	0.56	0.52	0.56
	16.0	12.4	6.7	6.0	6.1	3.6	5	0	0	0	0	0	26.0	0.42	0.54	0.54	0.56
	18.3	14.6	7.6	6.6	6.7	3.6	5	0	0	0	0	0	21.0	0.42	0.51	0.50	0.57
	17.0	13.2	7.7	6.3	6.5	3.7	5	0	0	0	0	0	20.0	0.45	0.58	0.46	0.57
	18.7	13.6	7.4	6.4	6.7	3.6	5	0	0	0	0	0	16.0	0.38	0.53	0.51	0.57
	20.4	13.1	6.1	5.6	6.4	3.2	6	0	0	0	0	0	16.0	0.30	0.47	0.52	0.50
	13.3	10.5	5.7	5.4	5.2	3.3	5	0	0	0	0	0	18.0	0.43	0.54	0.55	0.63
	14.7	10.3	5.6	4.6	5.4	3.0	7	0	0	P	0	0	20.0	0.38	0.54	0.54	0.58
	13.0	9.7	5.0	4.6	4.9	2.7	6	0	0	0	0	0	22.0	0.38	0.52	0.54	0.55
	16.8	13.7	6.8	6.6	6.6	3.7	6	0	0	0	0	0	22.6	0.40	0.50	0.54	0.56
MEAN	16.5	12.2	6.4	5.7	5.9	3.4	5.2	0.0	0.2		0.0		20.7	0.39	0.53	0.51	0.54
STANDARD DEVIATION	1.8	1.4	0.7	0.5	0.5	0.3	0.6	0.0	0.6		0.0		2.2	0.03	0.03	0.11	0.12
MAXIMUM	20.4	14.6	7.6	6.6	6.7	3.9	7.5	0.0	3.0		0.0		26.0	0.45	0.58	0.61	0.64
MINIMUM	13.0	9.7	5.0	4.7	4.9	2.7	4.0	0.0	0.0		0.0		16.0	0.30	0.47	0.00	0.00
Goniobasis ocheensis Lea, 1862 holotype USNM 119259	12.0	10.7	6.1	5.6	6.0	3.5	4.0	0	3	2AP 1P	2	BP,AP	37.0	0.47	0.57	0.87	0.58
paralectotypes USNM 873114 (N=26)	8.7	7.7	4.3	3.6	6.2	2.4	6.0	0	3	BP P	0	0	32.5	0.44	0.56	0.58	0.39
	11.7	8.1	5.6	4.6	5.2	2.6	3	5	5	P 3AP BP	3	AP,2BP	30.5	0.48	0.62	0.52	0.56
	10.4	6.5	4.7	5.4	6.1	3.5	6	0	0	0	3	AP BP P	48.0	0.45	0.55	0.74	0.57
	10.6	8.6	5.6	6.1	6.6	3.6	4	0	2	BP,P	2	BP,AP	40.5	0.53	0.63	0.64	0.55
	8.5	7.2	4.3	3.6	3.7	1.6	5	0	3	AP BP P	2	BP,AP	34.0	0.51	0.60	0.44	0.51
	8.9	7.9	4.7	7.0	6.7	4.2	5	0	3	2AP P	2	AP P	34.5	0.53	0.59	0.69	0.48
	8.6	7.6	4.5	3.6	4.1	2.4	6	0	0	0	2	AP P	39.0	0.48	0.57	0.53	0.59
	11.3	9.1	6.1	4.6	5.2	2.6	6	0	0	0	3	P,2AP	40.5	0.45	0.56	0.67	0.56
	11.6	9.6	6.6	4.7	5.3	2.6	4	0	0	0	2	BP P	35.0	0.48	0.57	0.52	0.58
	11.0	9.6	5.2	4.5	5.2	2.6	4	0	1	AP	1	BP	37.0	0.47	0.53	0.56	0.56
	10.2	8.5	4.8	4.3	4.7	2.5	6	0	2	P,AP	2	BP,AP	32.5	0.47	0.56	0.52	0.53
	8.7	6.7	4.1	3.5	3.7	2.2	6	0	3	P,2AP	2	BP,AP	20.0	0.47	0.61	0.54	0.59
	11.1	8.7	4.7	NA	NA	NA	6	0	1	AP	2	AP BP	36.0	0.42	0.54	NA	NA
	5.6	6.6	4.1	3.4	5.5	2.2	5	0	0	0	2	AP BP	26.5	0.48	0.62	0.54	0.63

TYPE SPECIMENS	L	2nd L	W	ApH	ApL	Ap	#Wh	R	BW	PBW	SW	PSpC	A	W/L	W/2nd	AW/AH	AW/AL
	9.9	9.0	4.4	3.9	4.5	2.5	4	0	1	AP	2	AP BP	31.5	0.44	0.55	0.57	0.56
	9.7	7.6	4.7	4.1	4.4	2.4	5	0	2	2AP	2	AP BP	24.5	0.48	0.62	0.51	0.55
	8.7	6.6	3.8	3.5	3.6	2.1	6	0	0	0	2	AP BP	27.5	0.44	0.58	0.55	0.58
	6.6	5.6	3.7	2.9	3.1	1.6	4	0	3	2AP P	2	AP BP	37.0	0.56	0.66	0.43	0.52
	10.4	8.7	4.7	4.2	4.6	2.5	5	0	3	P,2AP	2	AP BP	29.0	0.45	0.54	0.53	0.54
	9.1	7.6	4.5	3.6	4.0	2.3	4	0	0	0	2	AP BP	29.5	0.49	0.59	0.61	0.58
	7.0	5.9	3.6	2.9	3.0	2.0	5	0	3	P,2AP	2	BP,AP	38.0	0.51	0.64	0.56	0.67
	8.9	7.4	4.7	3.7	4.4	2.5	4	0	3	P,2AP	2	AP BP	37.5	0.53	0.64	0.53	0.57
	9.7	7.4	4.5	3.9	4.3	2.5	6	0	2	P,AP	2	AP BP	35.5	0.46	0.61	0.56	0.56
	8.5	6.5	3.9	3.3	3.5	1.9	6	0	3	P,2AP	2	AP BP	42.0	0.46	0.62	0.49	0.54
	8.7	7.7	4.0	4.1	4.4	2.7	4	0	3	P,2AP	2	AP BP	40.5	0.55	0.62	0.56	0.61
	8.9	6.6	4.4	3.3	3.5	2.2	4	0	3	P,2AP	2	AP BP	41.5	0.65	0.73	0.50	0.63
MEAN	9.6	7.6	4.0	4.1	4.7	2.6	4.6	0.4	1.6		2.9		34.8	0.46	0.60	0.56	0.56
STANDARD DEVIATION	1.5	1.3	0.6	1.0	1.3	0.6	0.9	1.4	1.4		0.5		6.0	0.05	0.04	0.09	0.06
MAXIMUM	12.9	10.7	6.1	7.6	8.7	4.2	6.0	6.0	5.0		3.6		46.0	0.65	0.73	0.56	0.67
MINIMUM	6.6	5.6	3.6	2.6	3.0	1.6	2.0	0.0	0.0		0.0		20.0	0.42	0.53	0.43	0.39
Goniobasis viennaensis Lea 1862 lectotype USNM 118743	21.6	18.7	9.3	8.7	8.7	6.1	7	14	6	P 4BP 3AP	2	,2AP	35.5	0.43	0.56	0.56	0.53
paralectotypes, USNM 573110 (N=2)	16.5	13.7	7.7	6.6	7.4	4.1	4	0	1	P	1	P	40.0	0.47	0.56	0.53	0.55
	19.3	14.3	7.8	7.5	8.0	4.1	6	5	0	0	1	BP	46.0	0.43	0.55	0.53	0.51
MEAN	18.8	14.6	8.3	7.6	8.4	4.4	5.7	6.3	3.0		1.5		41.5	0.44	0.55	0.54	0.53
STANDARD DEVIATION	2.1	1.3	0.7	0.9	1.0	0.9	1.2	5.9	3.0		0.5		3.2	0.02	0.01	0.01	0.02
MAXIMUM	21.6	18.7	9.3	8.7	8.7	6.1	7.0	14.0	6.0		2.0		46.0	0.47	0.56	0.55	0.55
MINIMUM	16.5	13.7	7.7	6.6	7.4	4.1	4.0	0.0	0.0		1.0		36.5	0.43	0.55	0.53	0.51

APPENDIX D
LIMNOLOGICAL DATA OF THE FIELD LOCALITIES OF THE SOUTHEASTERN *ELIMIA*

APPENDIX D Limnological Results for the Sites sampled from the southeastern Rivers

RIVER BASIN	SITE #	DATE	SPECIES	TEMP °C	CONDUCTIVITY (microS/cm)	DO (ppm)	ACIDITY (mg/l CaCO3)	ALK (mg/l CaCO3)	pH	DISSOLVED SOLIDS (g)
Alabama	2	25-May-96	*E. fallaina*	24	126	16.4	2	72	7.48	0.05
Alabama	3	25-May-96	*E. fallaina*	23	44	15.8	2	26	7.67	0
Alabama	5	24-May-96	*E. fallaina*	21.5	105	16	2	96	7.48	0
Alabama	6	24-May-96	*E. fallaina*	24	353	12.5	2	144	7.4	0.05
Alabama	7	24-May-96	*E. fallaina*	20	286	10.6	14	15	7.62	0
Escambia	14	23-May-96	*Elimia* species "A"	29	196.6	6.6	4	114	7.03	0
Escambia	16	23-May-96	*Elimia* species "A"	25	102.2	12.8	6	42	5.96	0.01
Escambia	29	24-May-96	*Elimia* species "A"	21	365	11	20	196	7.96	0
Choctawhatchee	44	26-Feb-95	*E. densicostata*	16	67	5.6	8	56	7.25	0.01
Choctawhatchee	45	26-Feb-95	*E. clenchi*	17	30	6.1	4	24	6.52	0.14
Choctawhatchee	46	26-Feb-95	*E. densicostata*	17	49	5.8	8	24	6.77	0.08
Choctawhatchee	48	26-Feb-95	*E. clenchi*	16	32	6.1	4	52	6.74	0
Choctawhatchee	49	26-Feb-95	*E. densicostata*	13	46	6	4	24	6.5	0.01
Choctawhatchee	50	25-Feb-95	*E. densicostata*	16	50	7.1	8	24	6.5	0.04
Choctawhatchee	51	25-Feb-95	*E. dickinsoni*	16	86	6.2	8	24	6.80	0.1
Choctawhatchee	54	26-Feb-95	*E. densicostata*	16	80	5	8	64	6.69	0.06

APPENDIX D--continued

RIVER BASIN	SITE #	DATE	SPECIES	TEMP °C	CONDUCTIVITY (microS/cm)	DO (ppm)	ACIDITY (mg/l CaCO3)	ALK (mg/l CaCO3)	pH	DISSOLVED SOLIDS (g)
Apalachicola	61	25-Feb-95	*E. densicostata*	16	130	6.2	6	24	7.1	0.04
Apalachicola	62	25-Feb-95	*E. densicostata*	24	166	5.7	6	56	7.38	0.02
Apalachicola	63	25-Feb-95	*E. densicostata*	24	150	7.2	6	116	6.84	0
Apalachicola	68	30-Nov-96	*E. ucheensis*	12	39.5	10.1	2	24	6.84	0
Apalachicola	70	30-Nov-96	*E. ucheensis*	13	45.1	11.4	2	36	6.98	0.01
Apalachicola	71	30-Nov-96	*E. ucheensis*	12	36.1	11.5	2	16	6.96	0
Apalachicola	83	13-Oct-95	*E. densicostata*	16	214	16.3	NA	NA	7.62	NA
Apalachicola	89	7-May-95	*E. viennaensis*	17.5	40	8.6	4	40	7.87	0.01
Apalachicola	90	7-May-95	*E. viennaensis*	17	55.7	8.6	6	32	8.13	0.07
Apalachicola	94	7-May-95	*E. viennaensis*	17	60	9.4	6	32	7.71	0
Altamaha	95	6-May-95	*E. mutabilis*	19.5	50	8	9	52	7.69	0
Altamaha	96	12-Oct-96	*E. timida*	20	NA	11.5	NA	NA	NA	NA
Altamaha	97	12-Oct-96	*E. timida*	23	196.8	14.5	4	112	7.77	0.35
Altamaha	98	12-Oct-96	*E. postelli*	16	126	9.5	16	100	7.81	0.34
Altamaha	99	12-Oct-96	*E. postelli*	16	126	15.3	4	32	7.71	0
Altamaha	102	11-Oct-96	*Elimia* species "C"	17.8	43	17.5	4	32	7.16	0.05

APPENDIX D —continued

RIVER BASIN	SITE #	DATE	SPECIES	TEMP °C	CONDUCTIVITY (microS/cm)	DO (ppm)	ACIDITY (mg/l CaCO3)	ALK (mg/l CaCO3)	pH	DISSOLVED SOLIDS (g)
Altamaha	103	11-Oct-96	*Elimia* species "C"	17	62	16.5	4	32	7.16	0.01
Altamaha	104	11-Oct-96	*Elimia* species "C"	17	92	16.3	16	36	7.02	0
Savannah	107	9-Oct-96	*E. postelli*	21	171.2	13	8	104	7.08	0.01
Savannah	109	4-Sep-96	*E. bentoniensis*	23	51.6	12	4	28	6.45	0

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BIOGRAPHICAL SKETCH

Elizabeth Louise Mihalcik was born May 28, 1964, in the Queens Borough of New York City, New York. She graduated from Orange Park High School in Orange Park, Florida, in June of 1981. She received her Bachelor of Arts degree in biology from the University of North Florida in May 1986. She worked for a period of time for the Department of Health and Rehabilitative Services as a clinical microbiologist in Jacksonville, Florida. She received her Masters of Science of Teaching degree in zoology from the University of Florida. She became introduced into the world of invertebrates through her mentor and friend, Dr. Fred G. Thompson. Miss Mihalcik decided to undertake a project in freshwater malacology for her doctoral research. She hopes to continue her research in freshwater and land malacology in the future by employing molecular techniques to unravel difficult taxonomic groups. Miss Mihalcik lives with her family of 5 dogs (2 maremmes, 1 Pembroke Welsh corgi, 1 Aussie-mix, 1 dachshund), 5 cats, 2 ferrets, 1 ungrateful conure, 1 cockatiel, and a variety of barn yard fowl. Her large family gives her peace of mind and enjoyment between her never ending tasks of taxonomic research. Her outside interests include nature photography, canoeing, and walking her dogs. She is also involved with the Central Florida Pyrenees Rescue and assisting people locally and through the internet solving pet behavior problems.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy

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